S+SNZ Annual conference, Building Back Better, Auckland 4-5 August 2021

The GeoNet and PositioNZ Continuous GNSS Networks: a geodetic infrastructure for Geohazards Monitoring

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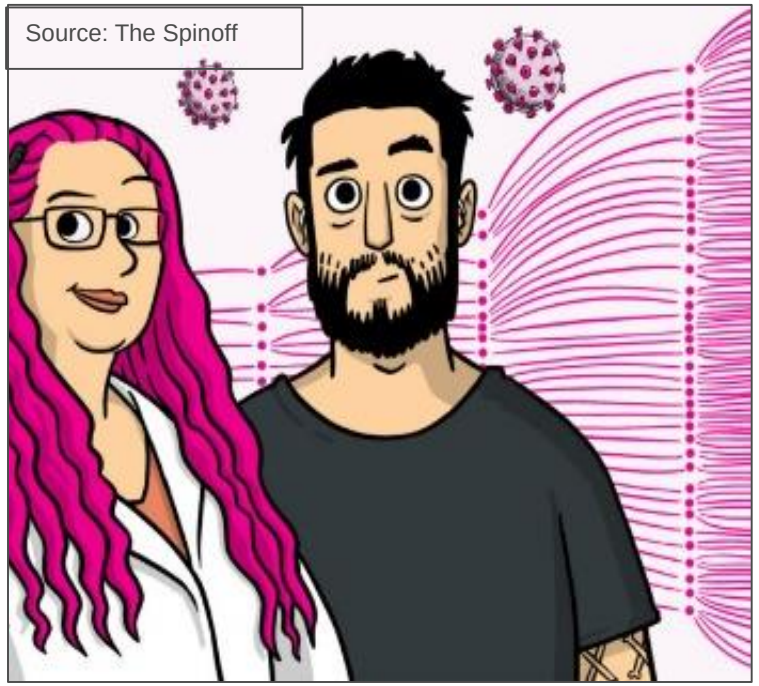
Outline

A little homage

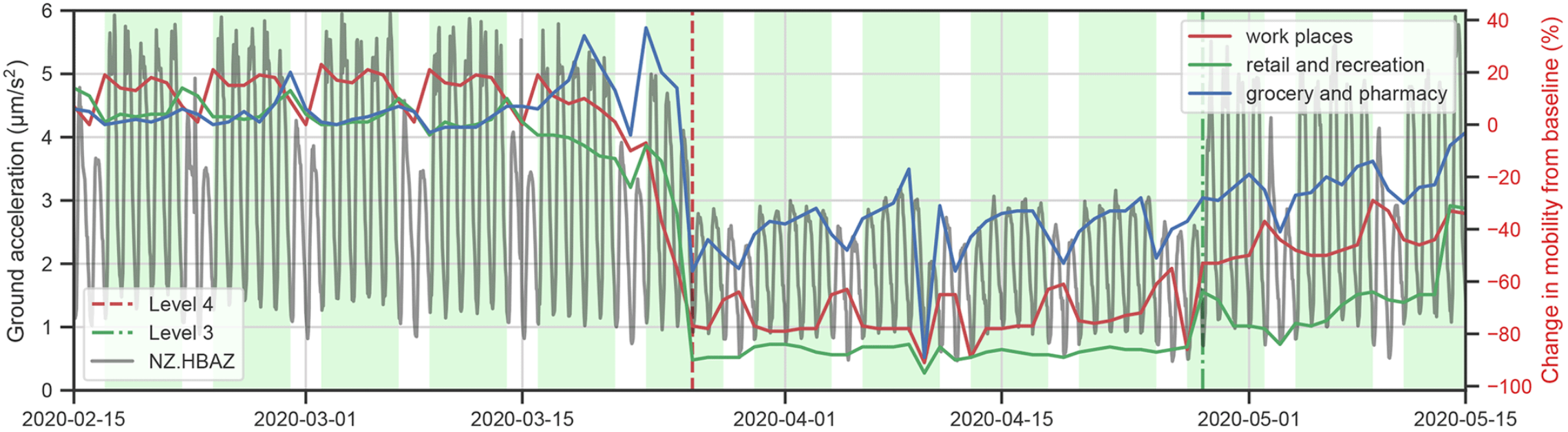
1. **Intro: What is GeoNet**
2. **GNSS: GeoNet and PositioNZ continuous GNSS networks**
3. **Events: GNSS for Event Response**
4. **Future: Future initiatives using GNSS data**



Thanks to Chris and the organization for the invite!

“Covid impact” on seismic data

- lower ambient noise during lockdown
- observed using RSAM (Real-time Seismic Amplitude Measurement) from HBAZ GeoNet seismometer
- Similar observations around the world



From Van Wijk et al., JGR Solid Earth, 2021, https://doi.org/10.5194/se-12-363-2021

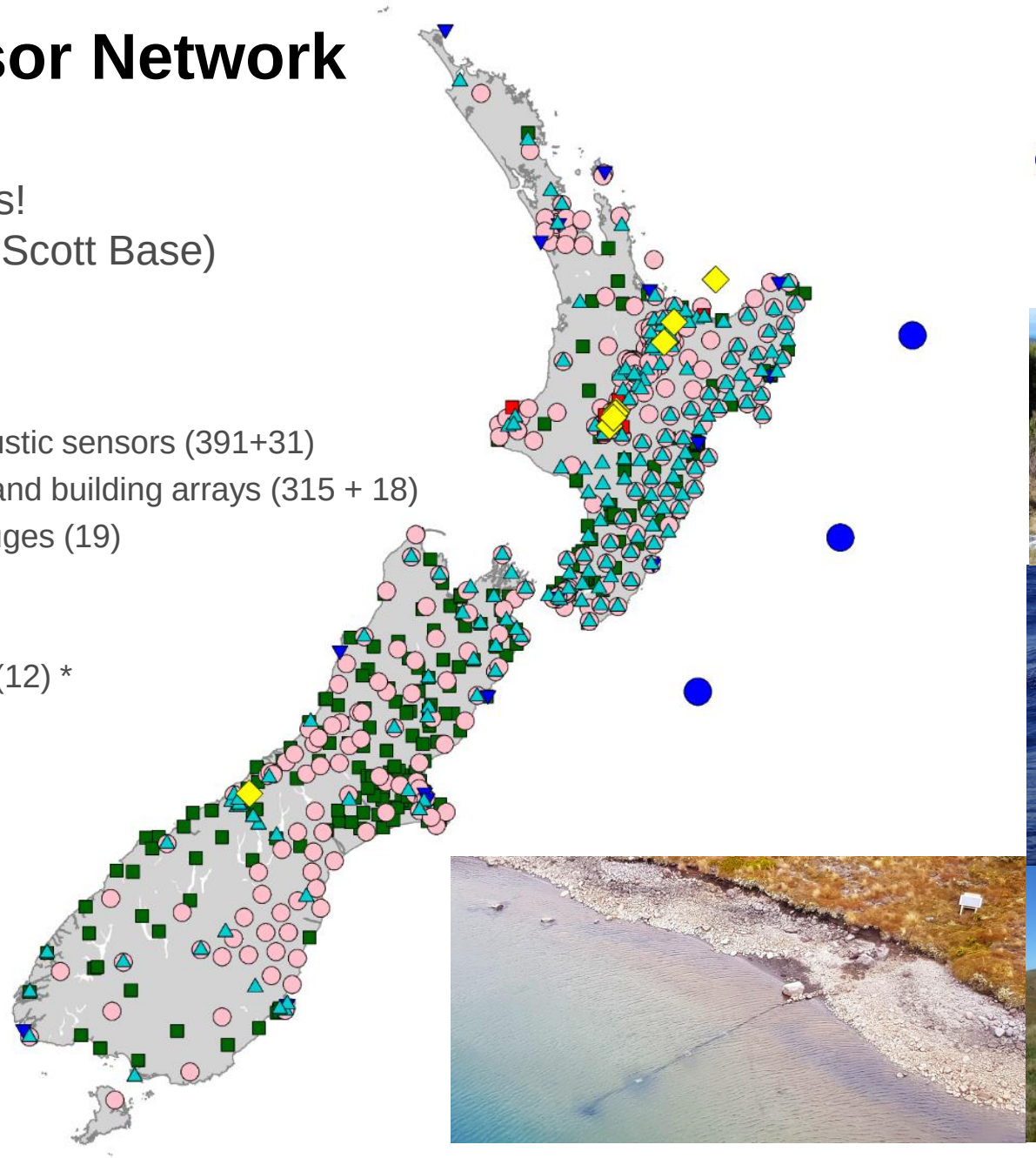
GeoNet, 20 years of monitoring geological hazards

- Earthquake
- Tsunami
- Volcano
- Landslide

GeoNet Sensor Network

Almost 1000 sensors!
(from Raul Island to Scott Base)

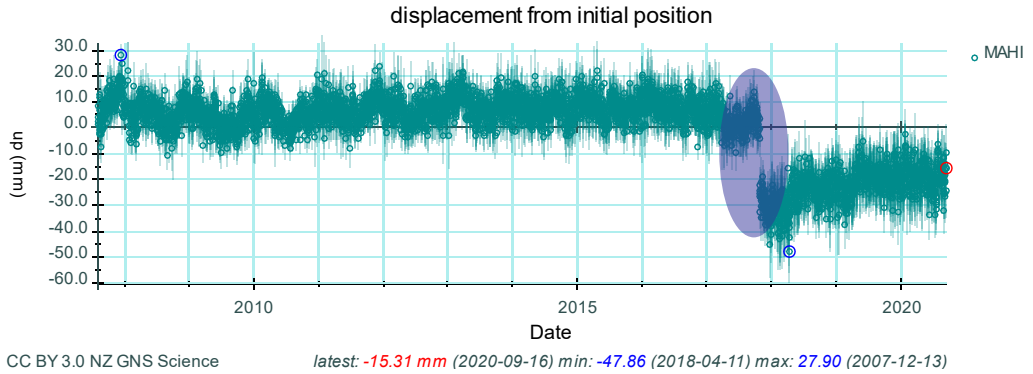
- GNSS sites (196)
- Seismometers and acoustic sensors (391+31)
- Strong motion sensors and building arrays (315 + 18)
- Tsunami monitoring gauges (19)
- DART (8) *
- Cameras (12)
- Environmental sensors (12) *



** DART and Environmental sensors collection, processing and distribution currently under development*

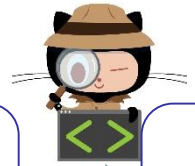
Sensor network metadata

- Robust metadata control process for scientific equipment changes
- version controlled database
- accessible to all end users (http://github.com/GeoNet/delta)



Technicians in the field collects information

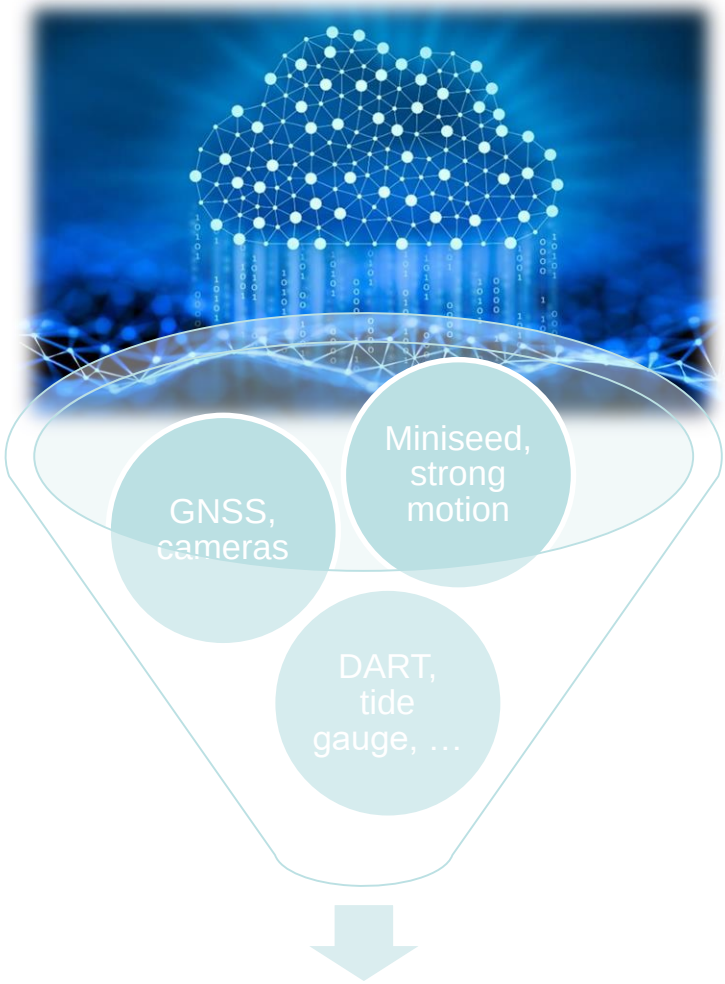
specialists control information against data and record change



metadata change is reviewed

change confirmed, downstream processes are automatically updated

Modern Data Management System and data archive



30 years of digital records

(raw and derived data)

- GeoNet Data moved to the cloud in 2018-2019
- Preparing for the future
  (cloud computing, data driven decision, artificial intelligence)

Current data volumes

64 TB

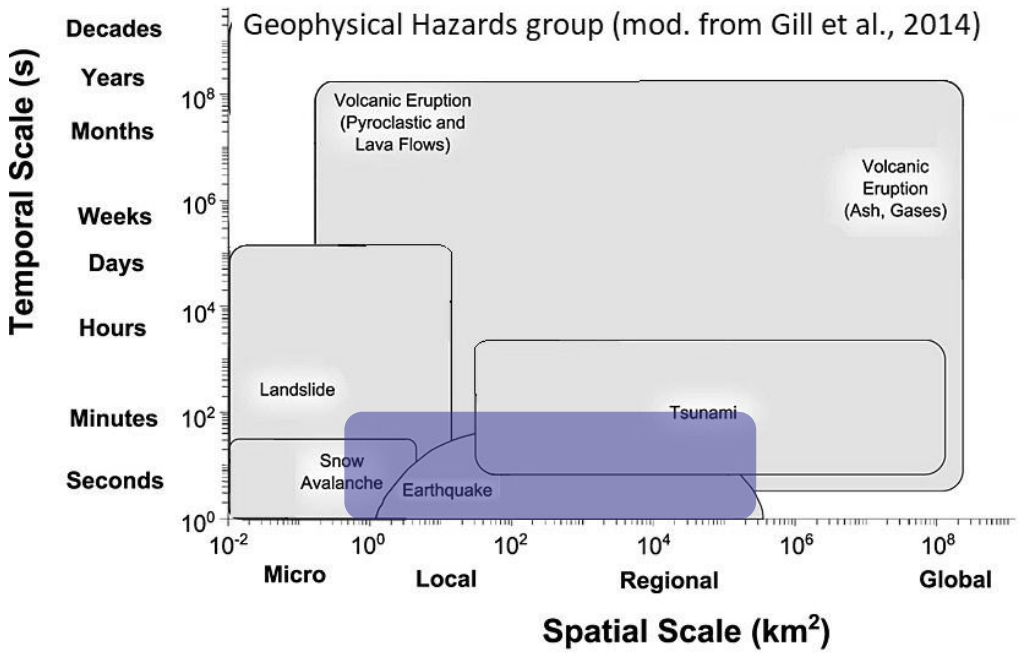
Rate

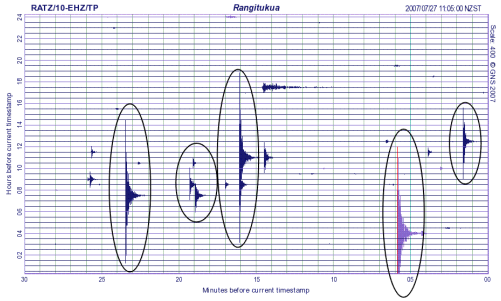
43 GB/day

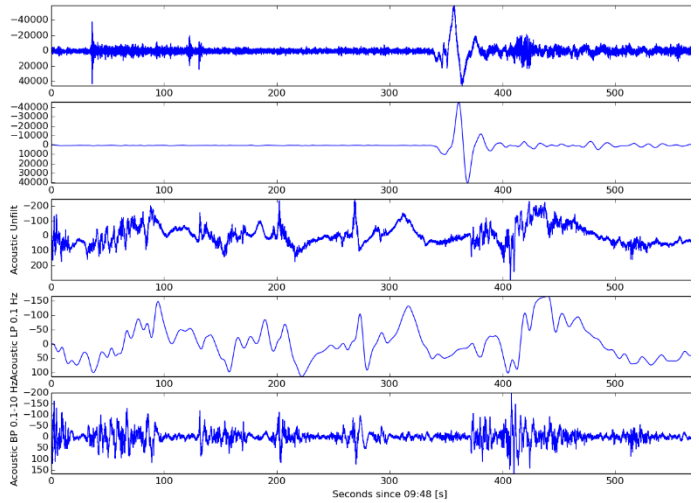
Estimated growth

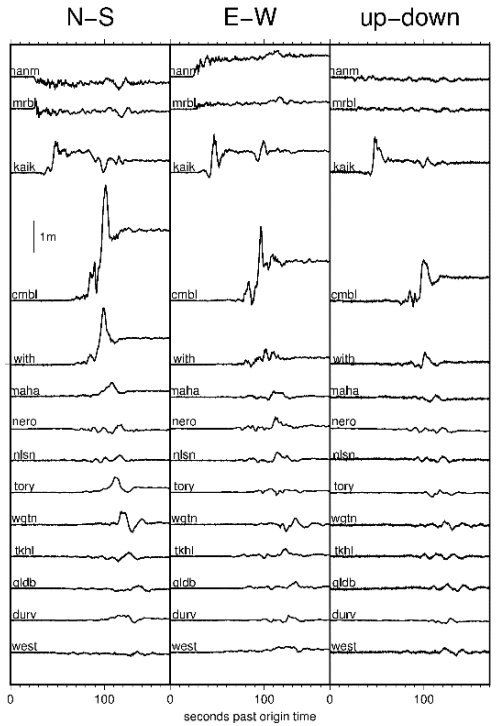
1.6 TB/year

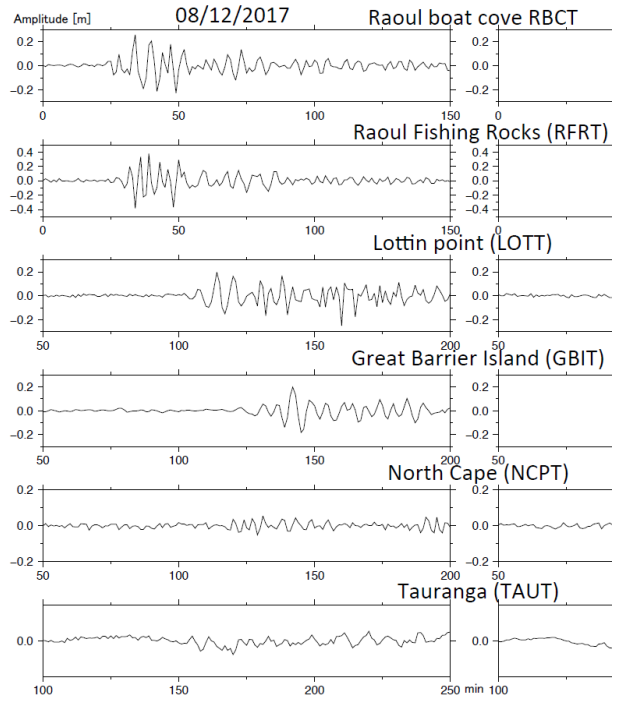
Data and products: from seconds…







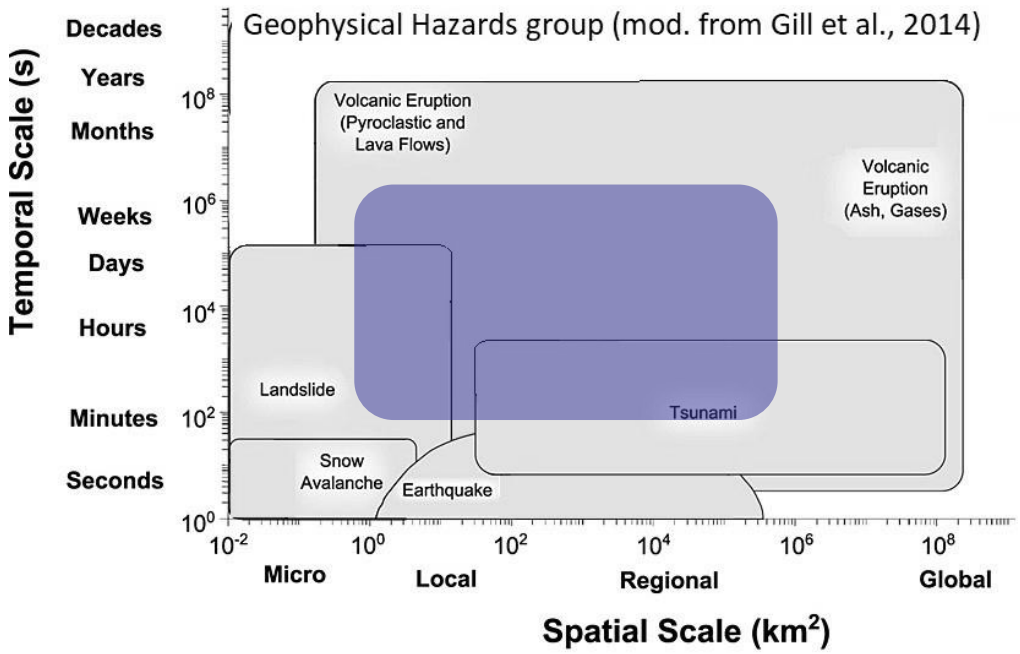


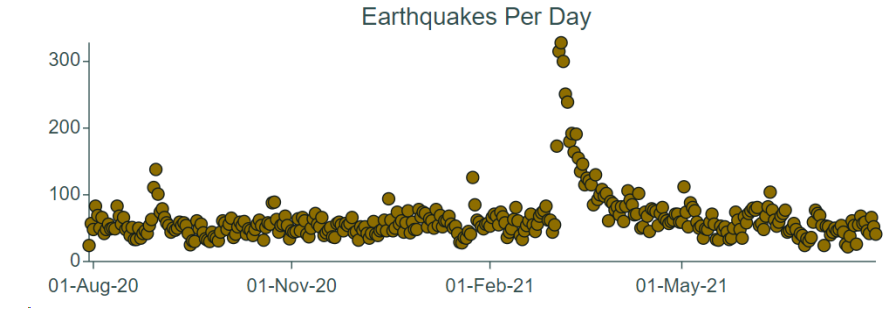


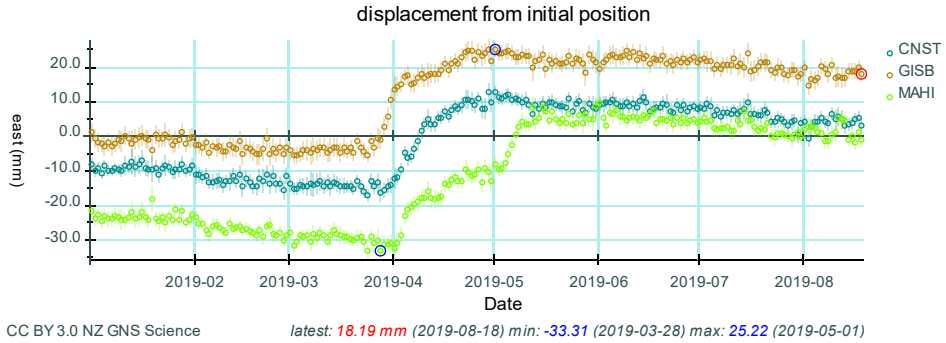
"Real Time" data:

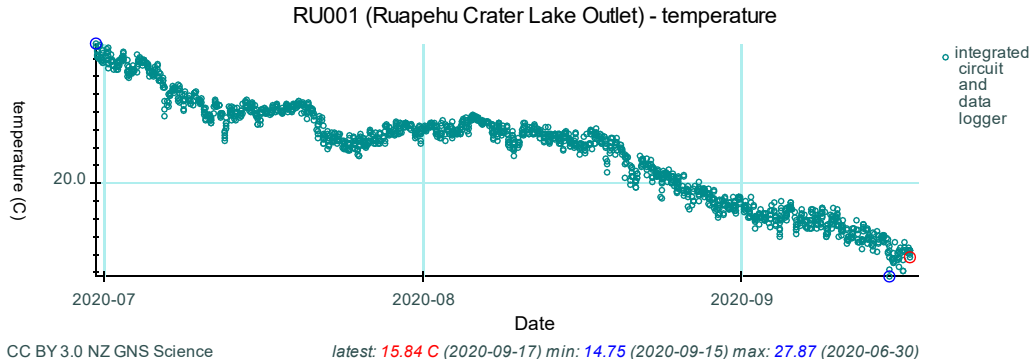
- Seismic
- Tsunami monitoring gauges
- GNSS
- Acoustic
- DART data

Data and products: …to days/months…





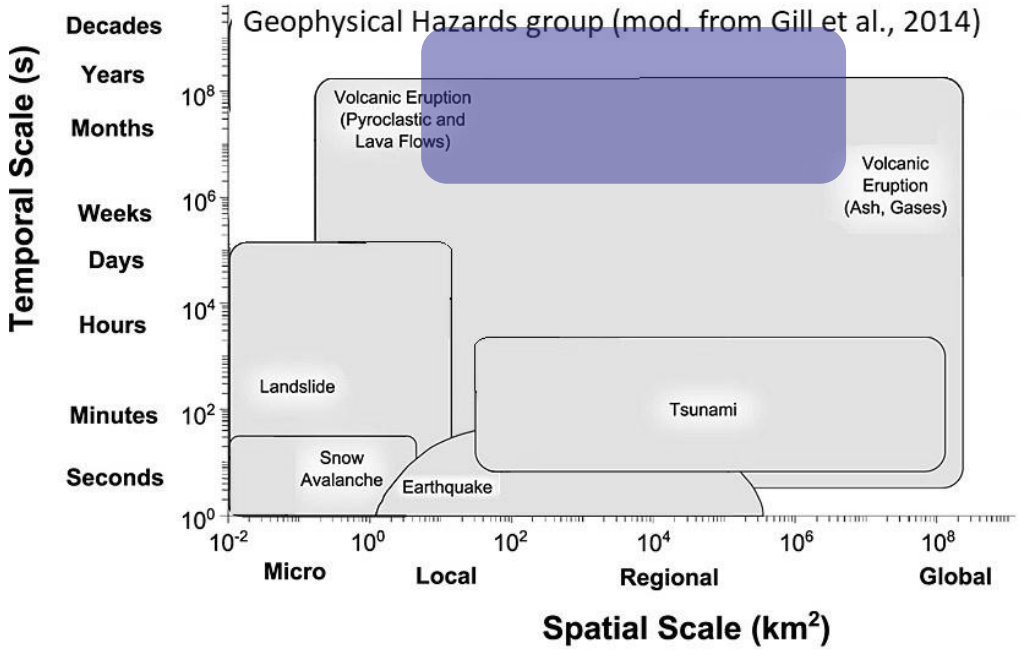


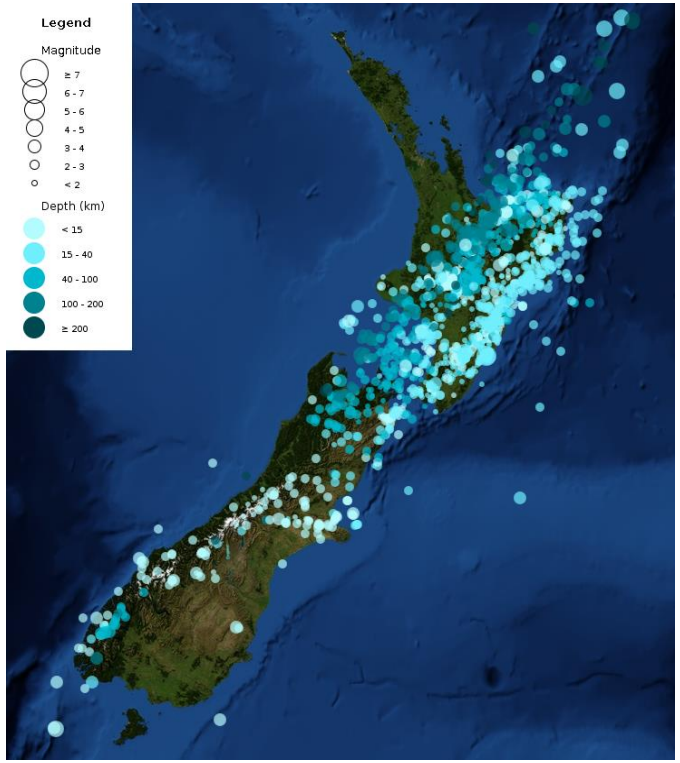


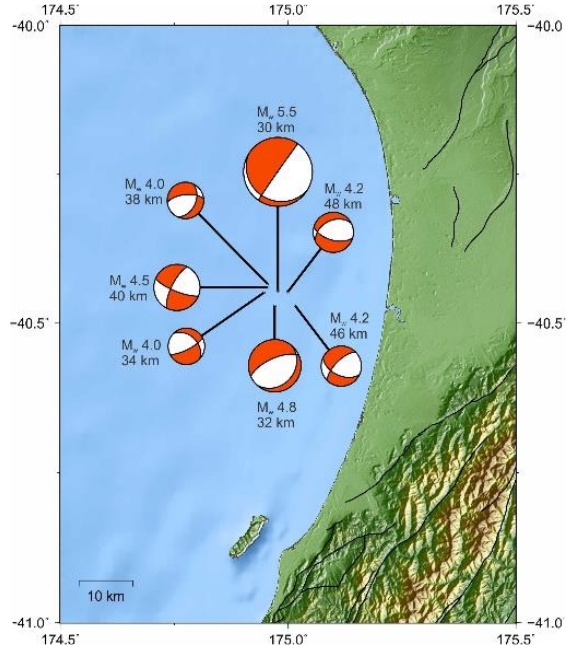
Medium/low-rate and campaign data

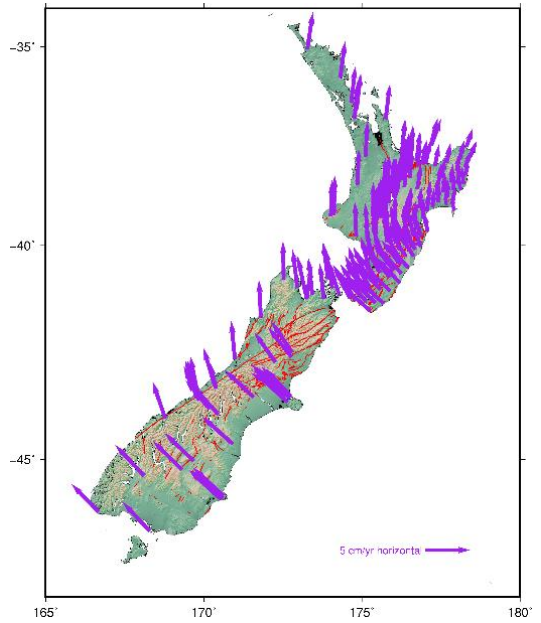
- Earthquake parameters
- Crater lake monitoring
- Volcano gas flux
- Webcams
- GNSS daily solutions

Data and products: …to decades



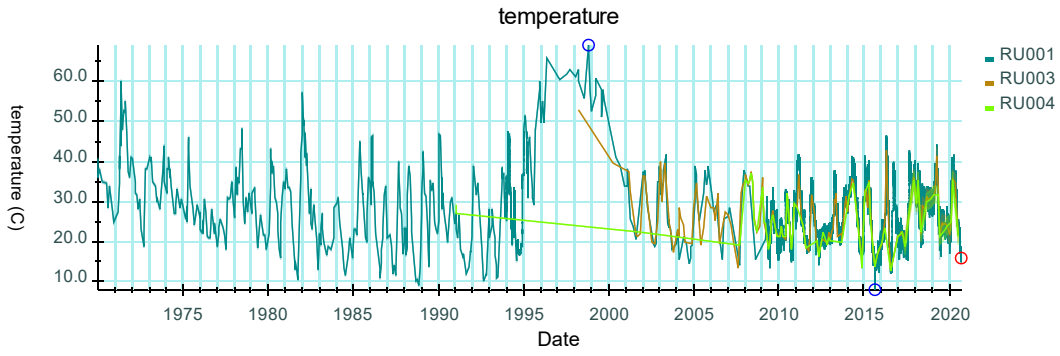






“Long term” data:

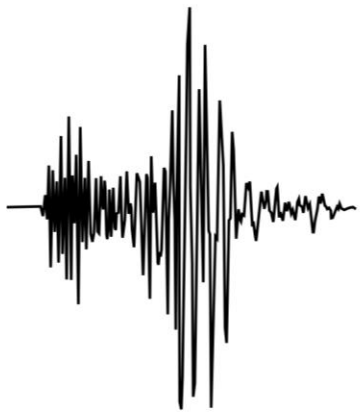
- Felt reports
- EQ catalogue (~627,400)
- Strong motion products
- Eruption history database
- Volcano alert levels and bulletins
- Landslide reports
- Long term ground deformation



GeoNet data used by NGMC to monitor geohazards

Established in December 2018

National Geohazards Monitoring Centre
Te Puna Mōrearea i te Rū

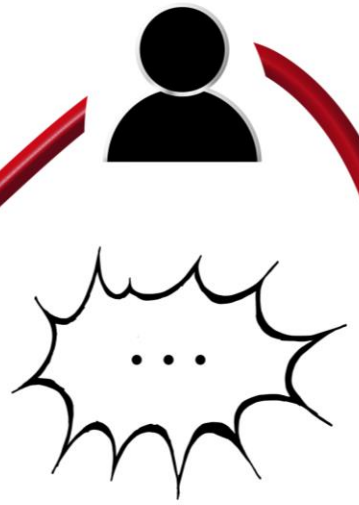


Earthquake

Analysis System

Geohazards Analysts
GHA

SDO
Seismic Duty Officer



GeoNet
Website
+ App

Ministry of Civil Defence
& Emergency Management
Te Rākau Whakamarumaru

National Geohazards Monitoring Centre

Te Puna Mōrearea i te Rū

Photo: Holly Godfrey

GeoNet and PositioNZ GNSS networks

20 years of partnership between GNS, LINZ, EQC, Otago University School of Surveying through the GeoNet Project (now Programme).

High value geographic information

National reference datum

Real time positioning

Ground deformation monitoring

GNSS data for research

GeoNet and PositioNZ continuous GNSS networks

Toitū Te Whenua Land Information New Zealand

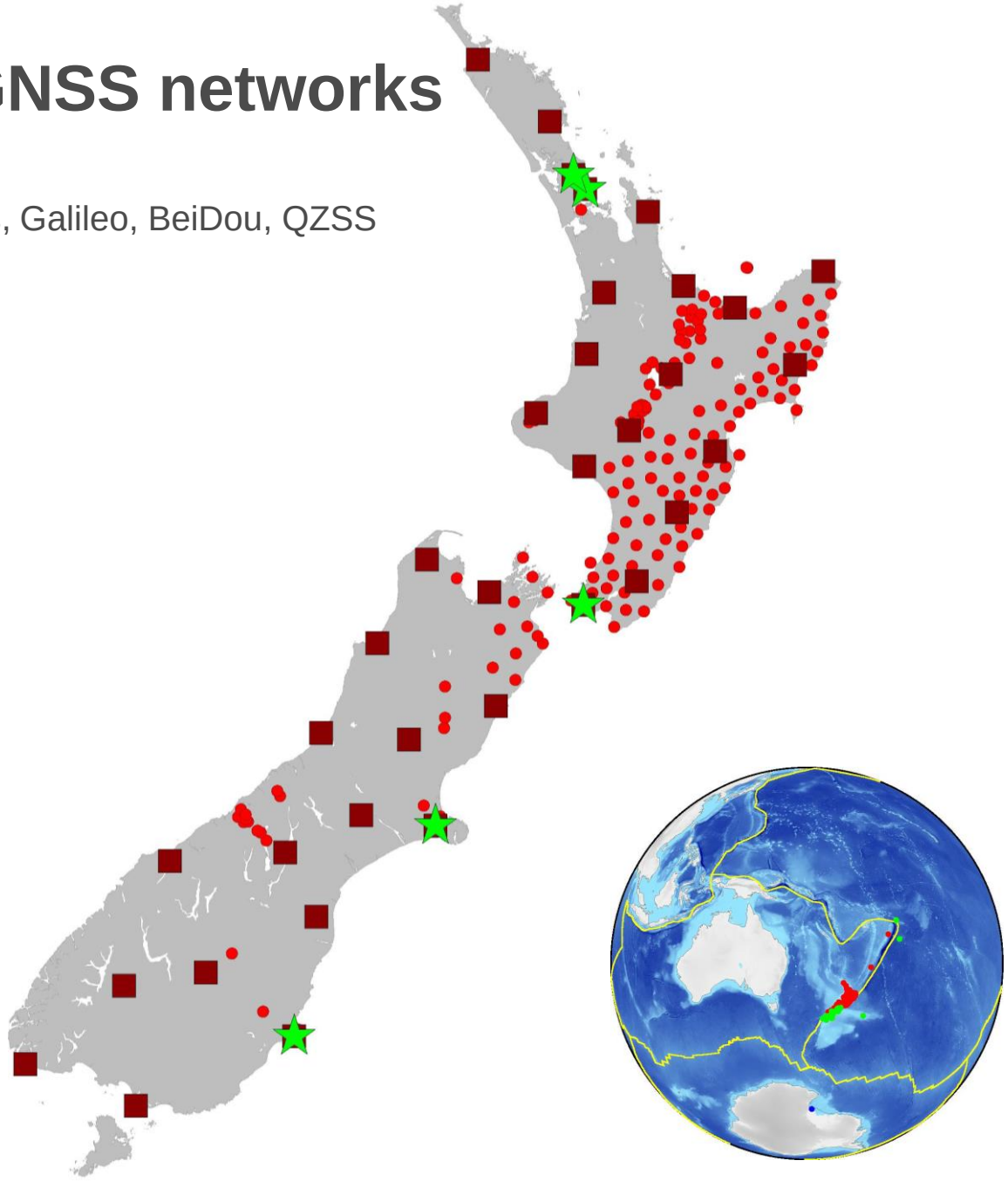
PositioNZ stations (37): GPS, Glonass, Galileo, BeiDou, QZSS
https://www.linz.govt.nz

GeoNet

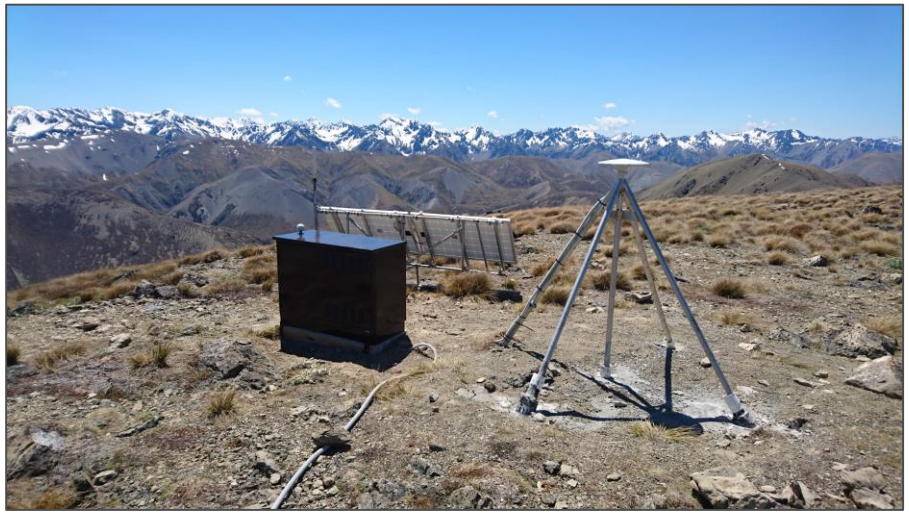
GeoNet stations (160): GPS, Glonass
https://www.geonet.org.nz

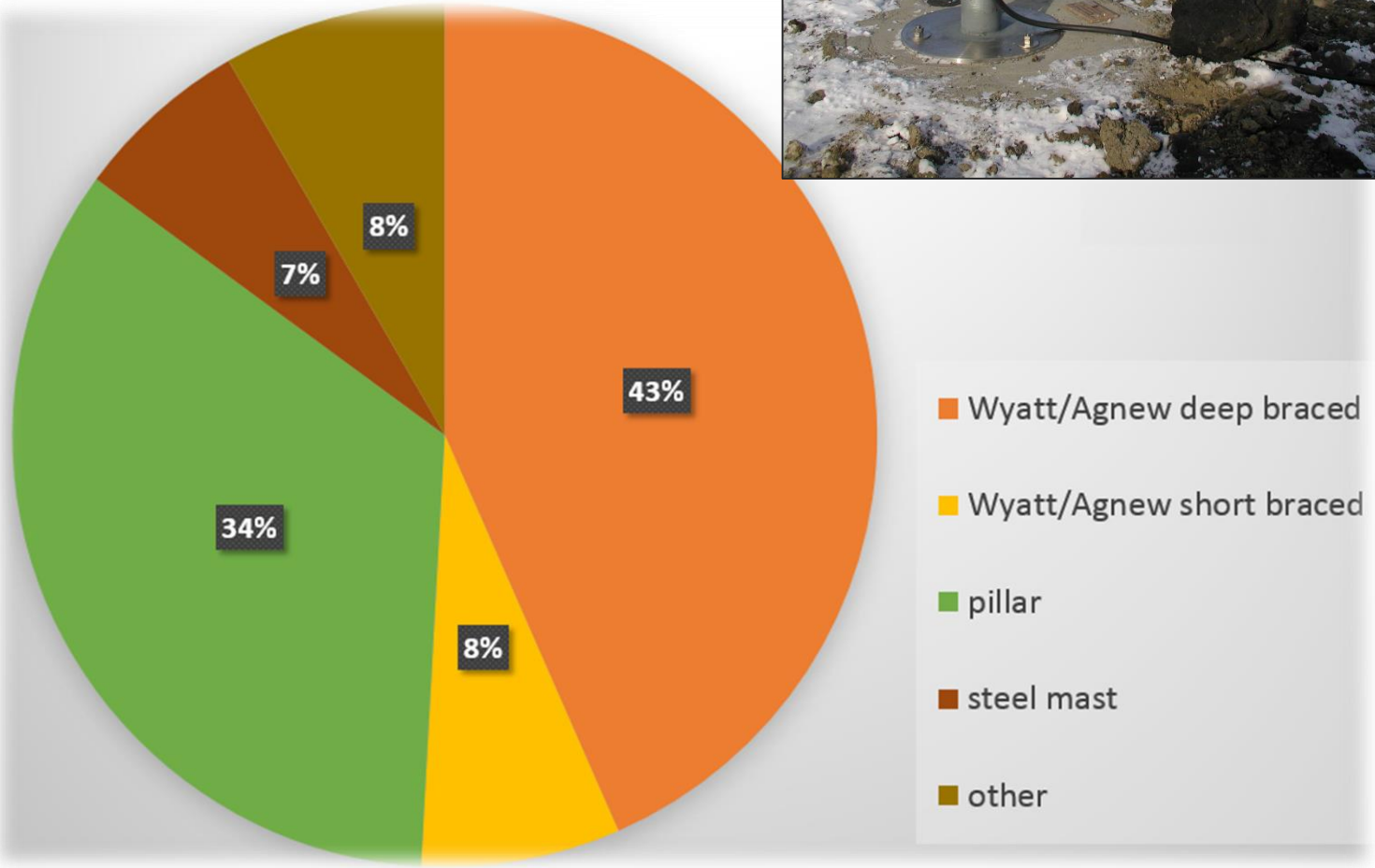
IGS INTERNATIONAL GNSS SERVICE

Contributing to **IGS network (7)**
www.igs.org



GNSS stations monument types





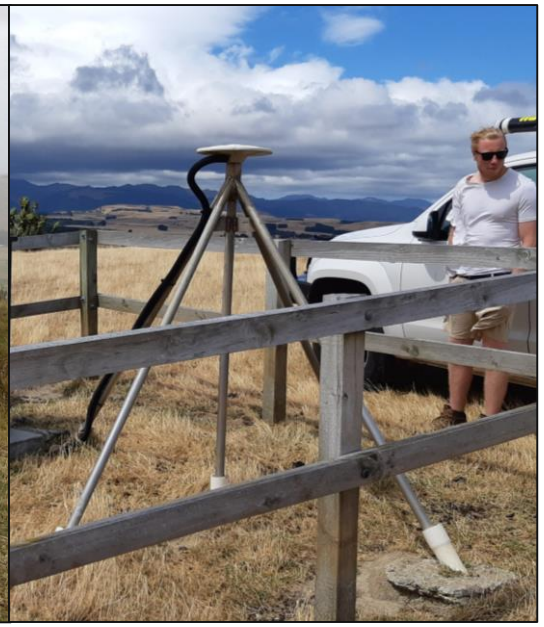
Wyatt/Agnew Deep Braced Monuments construction

Original design by Unavco, high quality GNSS monument:
- well anchored to the ground
- up to 10 m foundations depth
- stainless steel
- solid and durable antenna mount

Rotorua Highlands Station RGHL

North anchor	0.0	to	3.5	Soft brown ASH
	3.5	to	8.0	Fractured IGNIMBRITE
South anchor	0.0	to	4.7	Soft Brown ASH
	4.7	to	8.0	Fractured IGNIMBRITE
East anchor	0.0	to	3.9	Soft brown ASH
	3.9	to	7.5	Fractured IGNIMBRITE
West anchor	0.0	to	4.1	Soft brown ASH
	4.1	to	8.5	Fractured IGNIMBRITE
Centre anchor	0.0	to	4.2	Soft brown ASH
	4.2	to	9.5	Fractured IGNIMBRITE



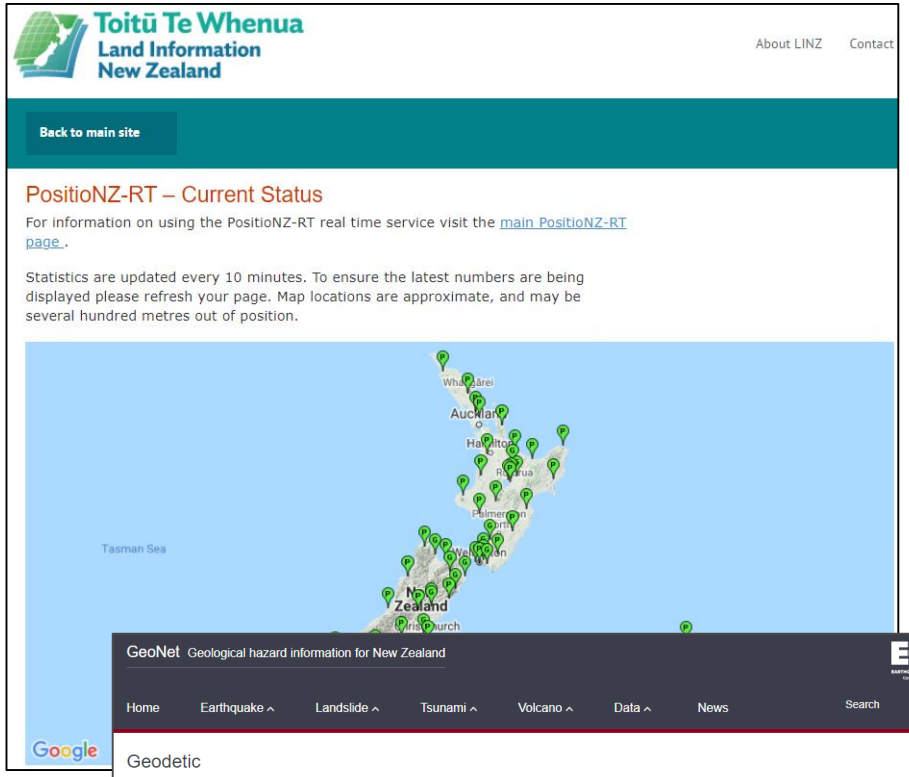
GNSS data products: where to find them

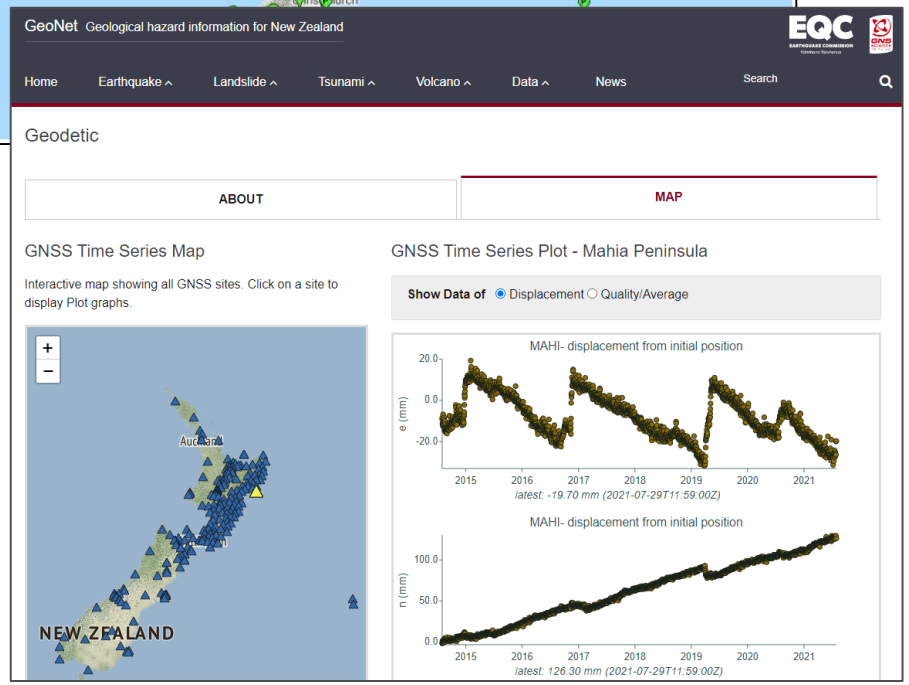
- **RINEX and raw data**
  https://www.geonet.org.nz/data/types/geodetic
  https://data.geonet.org.nz/gnss

- **1s real time GNSS streams (~20% of sites)**
  https://www.linz.govt.nz/data/geodetic-services/positionz/positionz-real-time-service

- **Daily position time series**
  to visualize: https://www.geonet.org.nz/data/gnss/map
  to download: FITS https://fits.geonet.org.nz/api-docs/

** 1 Hz data can be manually retrieved from sensors in the field upon request to support surveying*

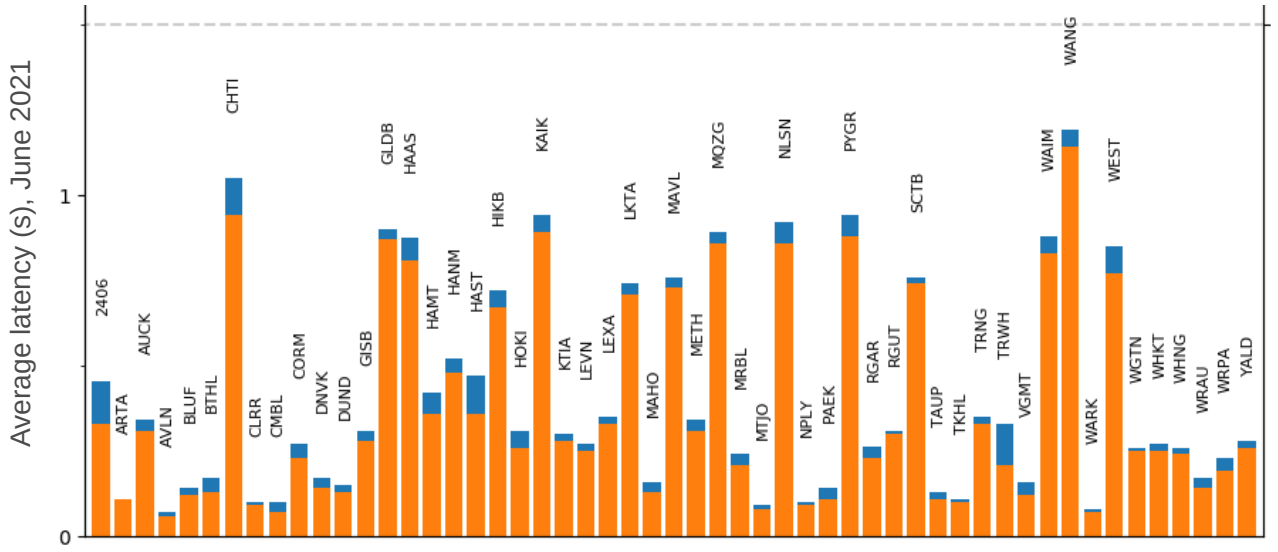


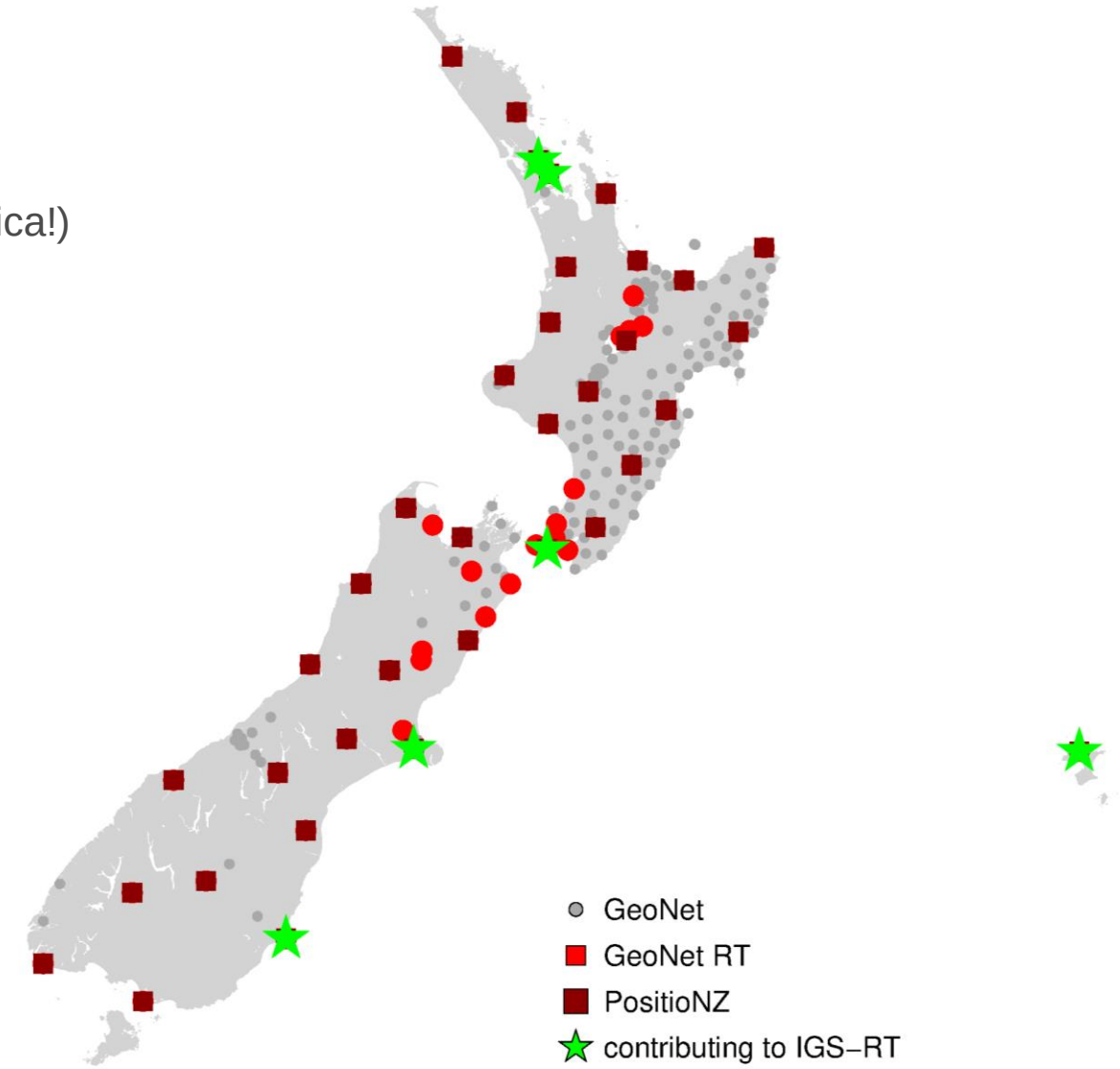


PositioNZ Real Time network

Real time service:

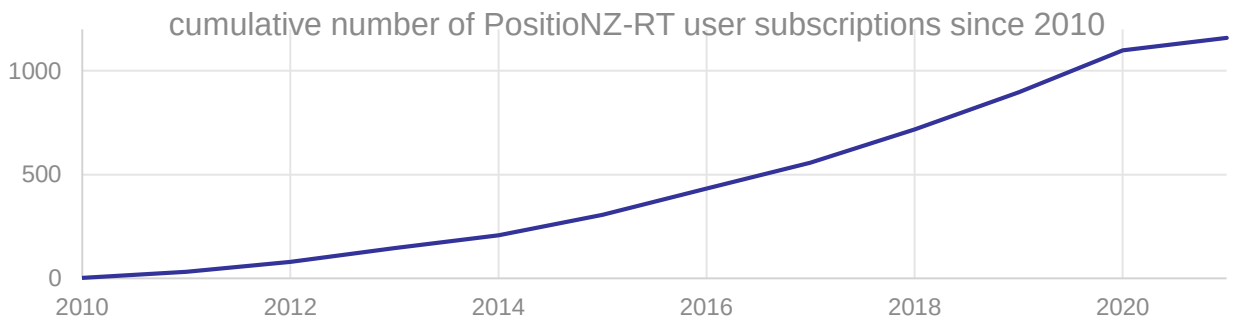
- **53 streaming stations**
  - all 37 PositioNZ stations (including Scott Base in Antarctica!)
  - 10% of GeoNet stations (16)
- **Streaming of 1s GNSS data in real time**
- **~1000 individual connections at any given time**
- **less than 1.5 seconds latency on average**



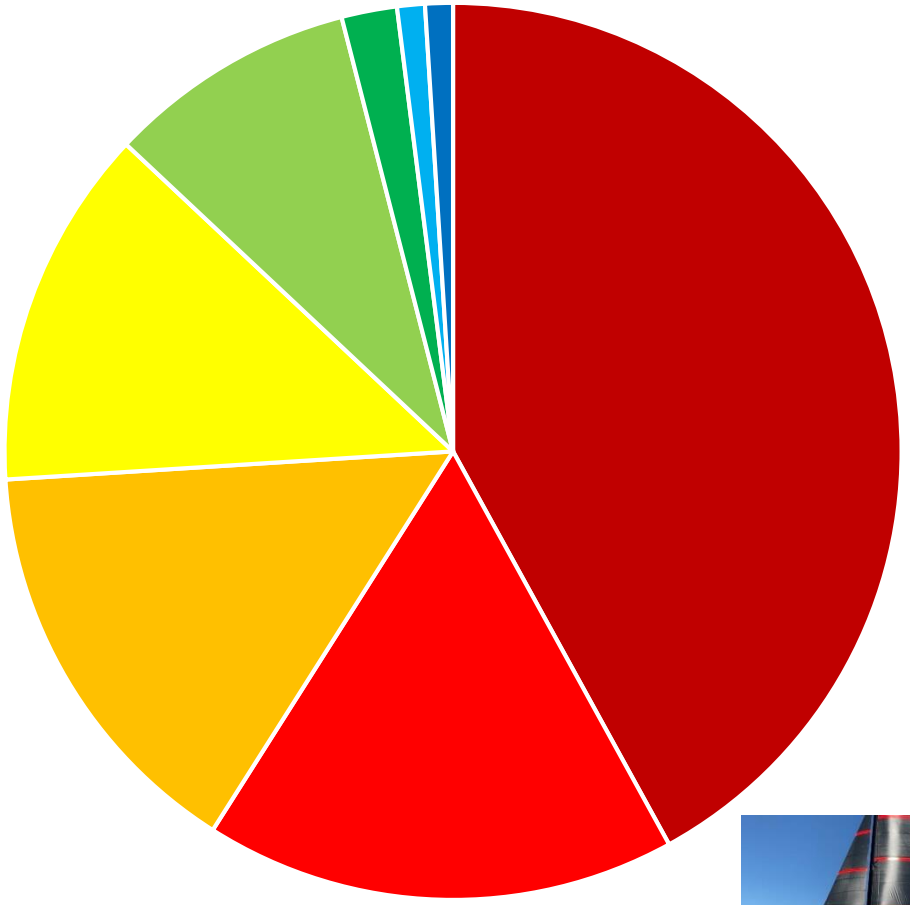


PositioNZ Real Time users

- User subscriptions statistics (courtesy of S. King, LINZ)

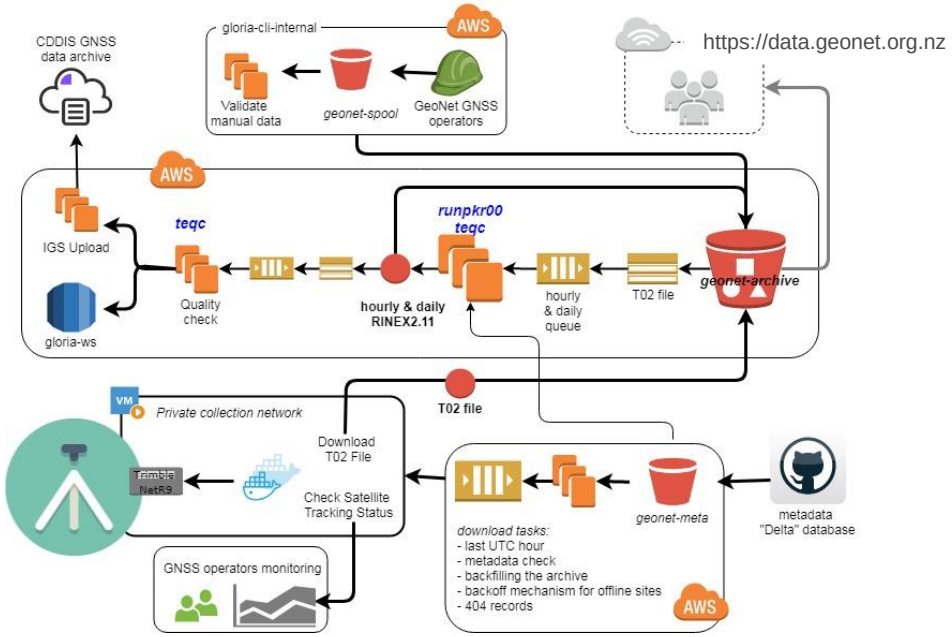


- Individual connections (May-June 2021)

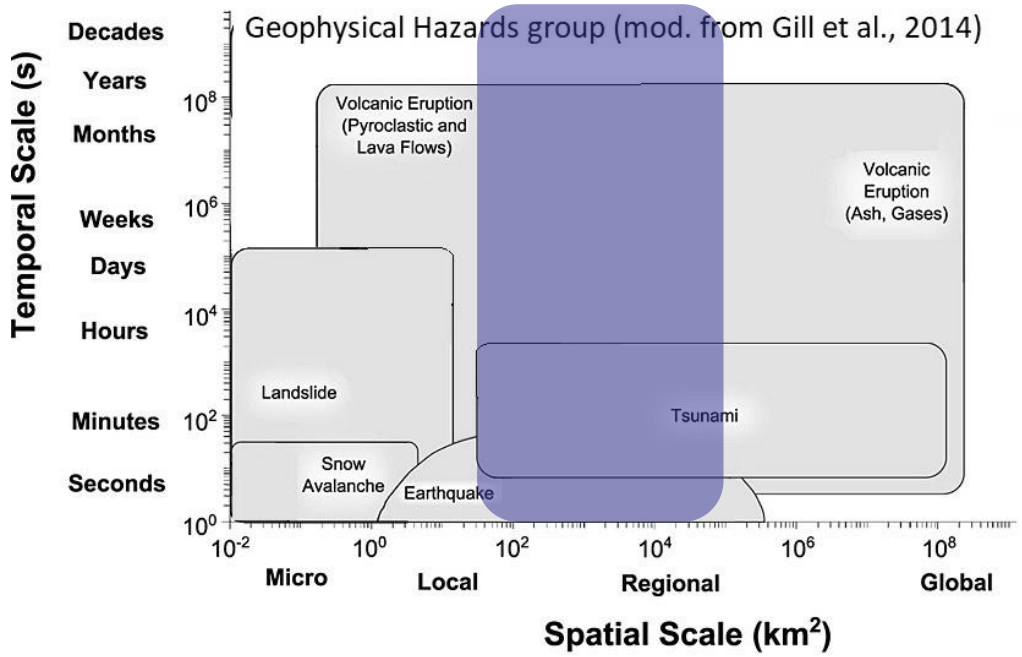


Recent GeoNet projects in partnership with LINZ

- GNSS data collection modernization (2017-2018)
- GNSS sensor network upgrade and vertical reference marks measurements (2019-2020)
- PositioNZ-RT streams renaming and users migration to align with IGS standards (2020-2021)



How GeoNet and PositioNZ GNSS networks support response to large geohazard events



- Earthquake
- Tsunami
- Volcano
- Landslide

Kaikoura 2016 earthquake, M 7.9

10,000+ landslides

21 identified faults

15,840 online reports within the first hour

3 slow slips triggered

250 million hits to GeoNet website on 14th November

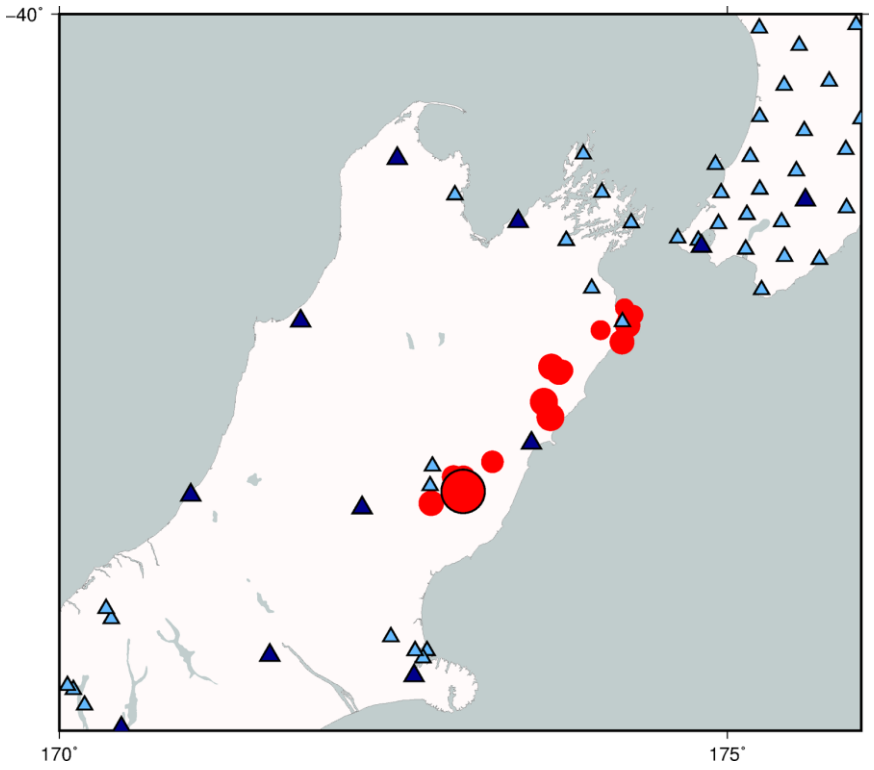
still under investigation 3g+ peak ground acceleration (PGA) recorded at Waiau

19,000+ aftershocks

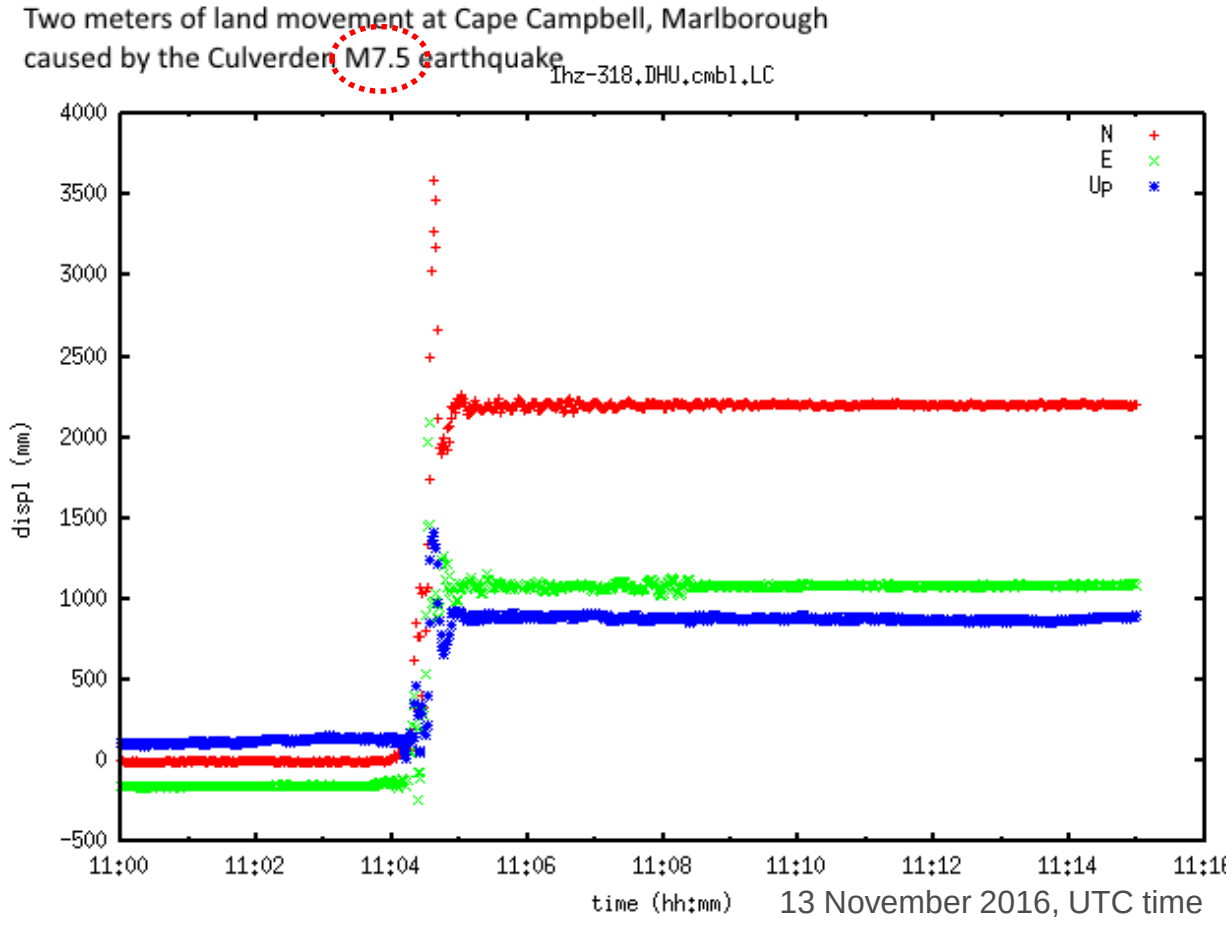
6.9m tsunami at Goose Bay

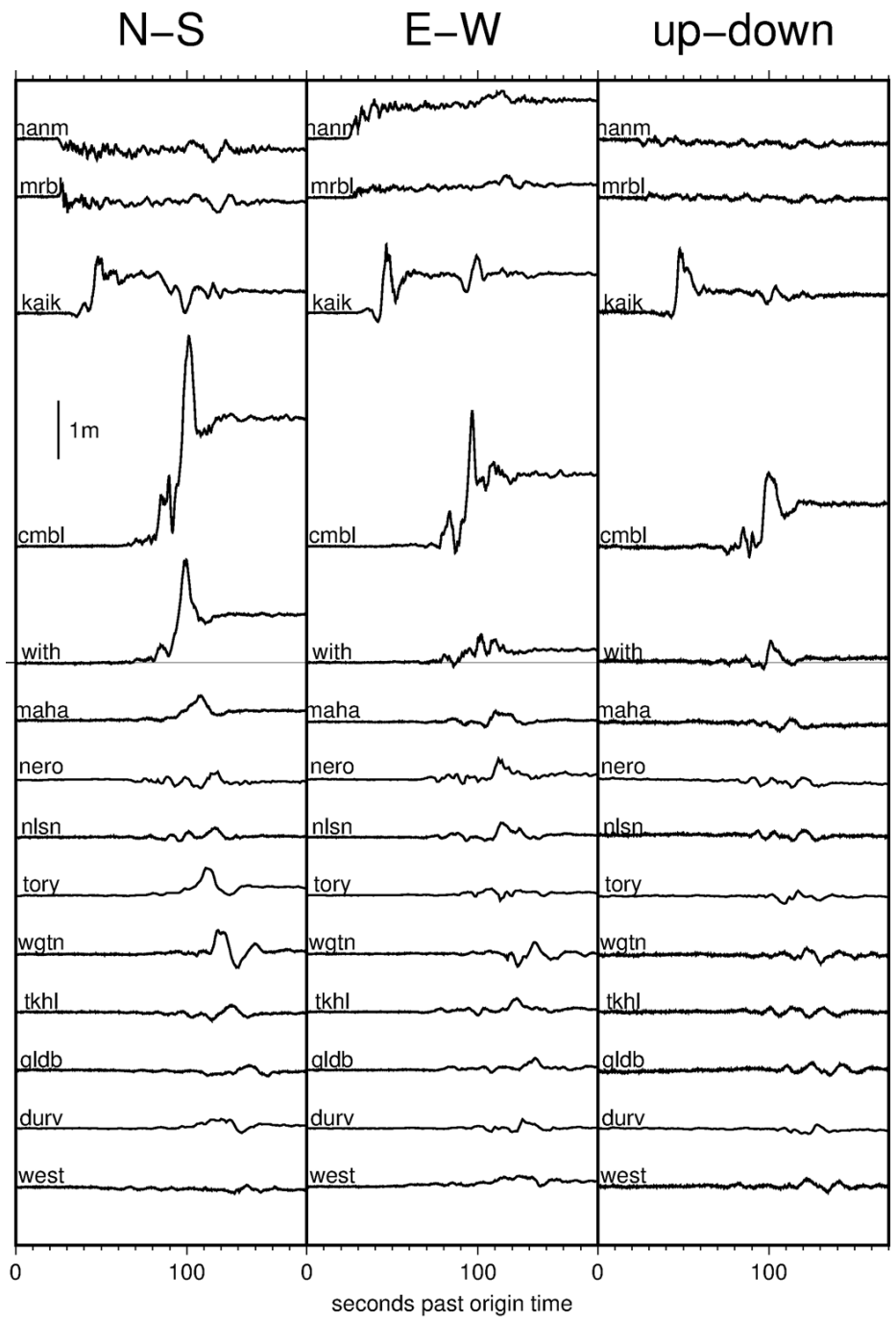
Kaikoura 2016 earthquake, time machine

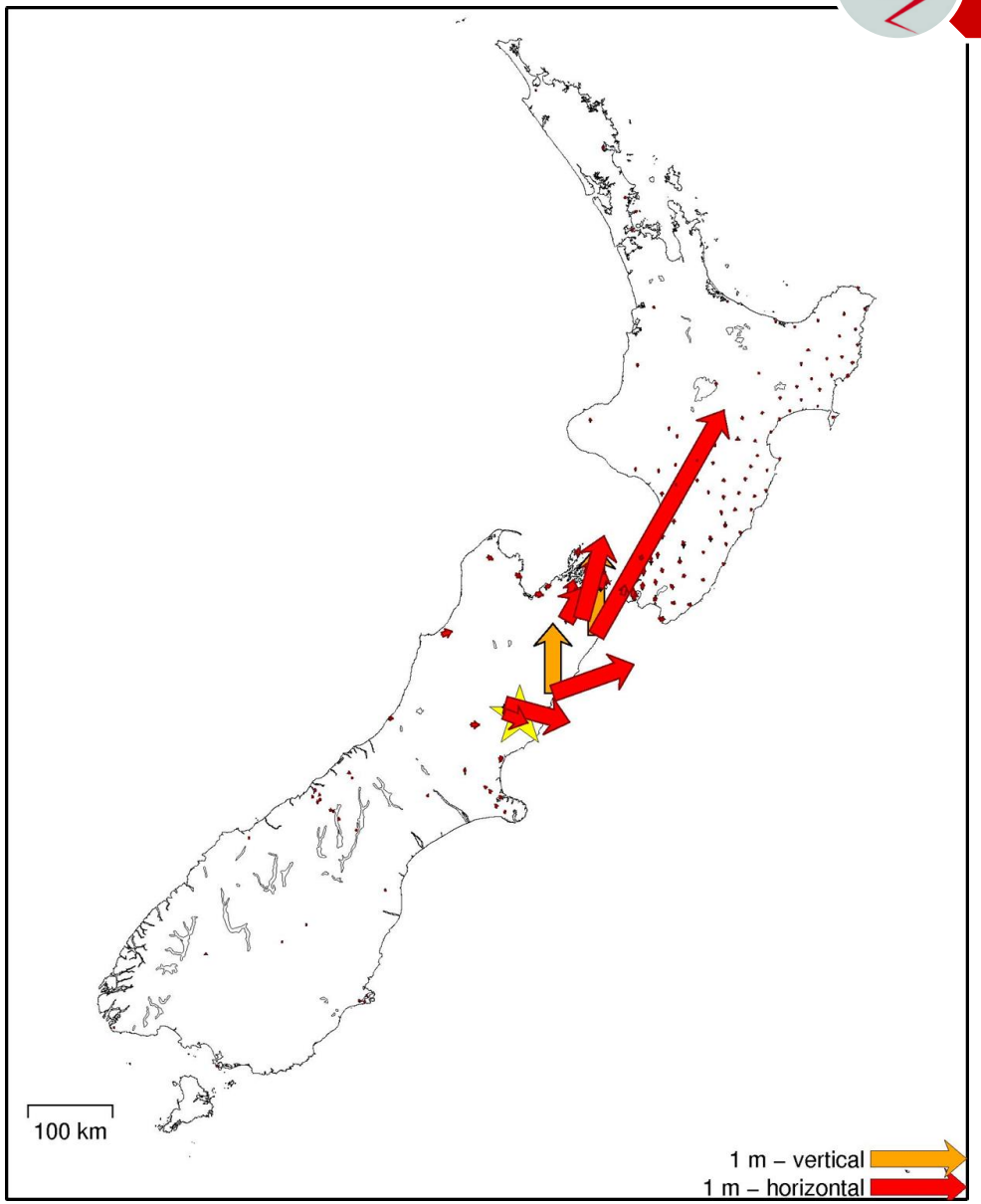
GNSS network in November 2016



GNSS “kinematic displacement”, produced (manually) ~2hr after the event. Earthquake magnitude was still poorly constrained by available data and modelling







Kaikoura 2016, coseismic deformation

Coseismic displacement measured by GNSS stations:

- "dynamic", every 0.1sec (plots on the left)
- "static", from daily solutions (map on the right)

Kaikoura 2016, GeoNet Network Team rapid response

6 new GeoNet GNSS stations sites installed within a week after the event!

In the weeks following the Kaikōura event our technicians were busy installing new instruments in the region to help us better locate the many aftershocks, and see how the land was behaving/ moving. This included adding both temporary and new permanent stations to our national network.

NEW SITES

GNSS with strong motion

GLOK	GLOS	Glen Orkney
LOOK	LOKS	Mt Lookout
SEDD	SDNS	Seddon
WRAU	WRAS	Wairau Valley

GNSS with weak and strong motion

CLRR	CRSZ	Clarence River Middle Hill

NEW TEMPORARY SITES

Temporary GNSS with strong motion

TEN2	TENS	Lake Tennyson (will be made permanent)
MUL1	SM1F	Muller Station
GDS1	SM2F	Gladstone Station
LOK1	SM3F	Glen Orkney (temporary station)

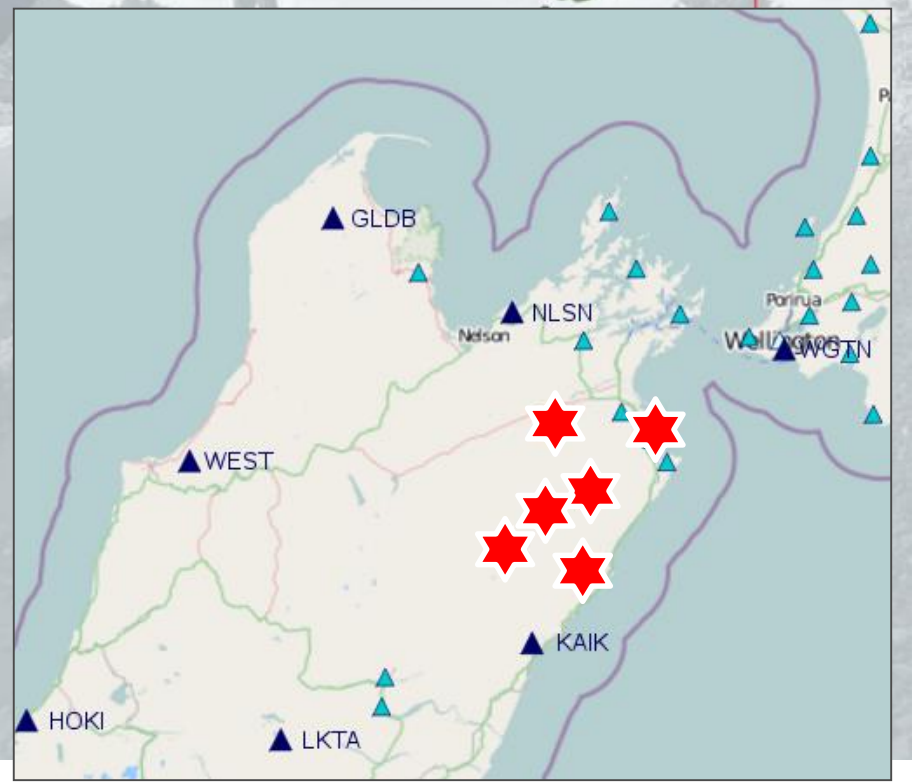
ADDITIONS TO EXISTING SITES

Strong motion added to regional seismic and sites upgraded

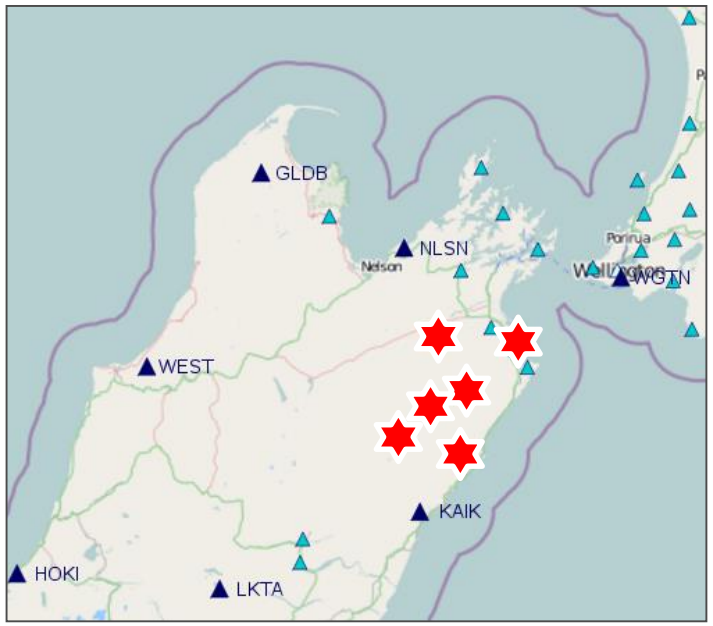
TUWZ		Tuamarina
BSWZ		Blackbirch Station
CMBL	CMWZ	Cape Campbell

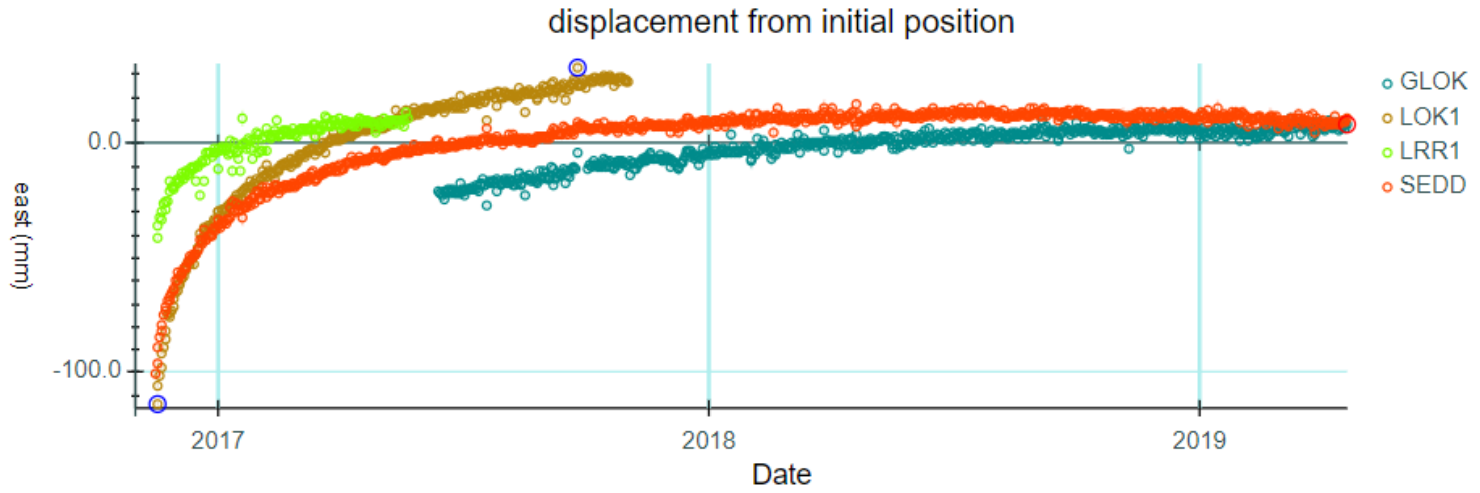
Temporary weak motion added to strong motion

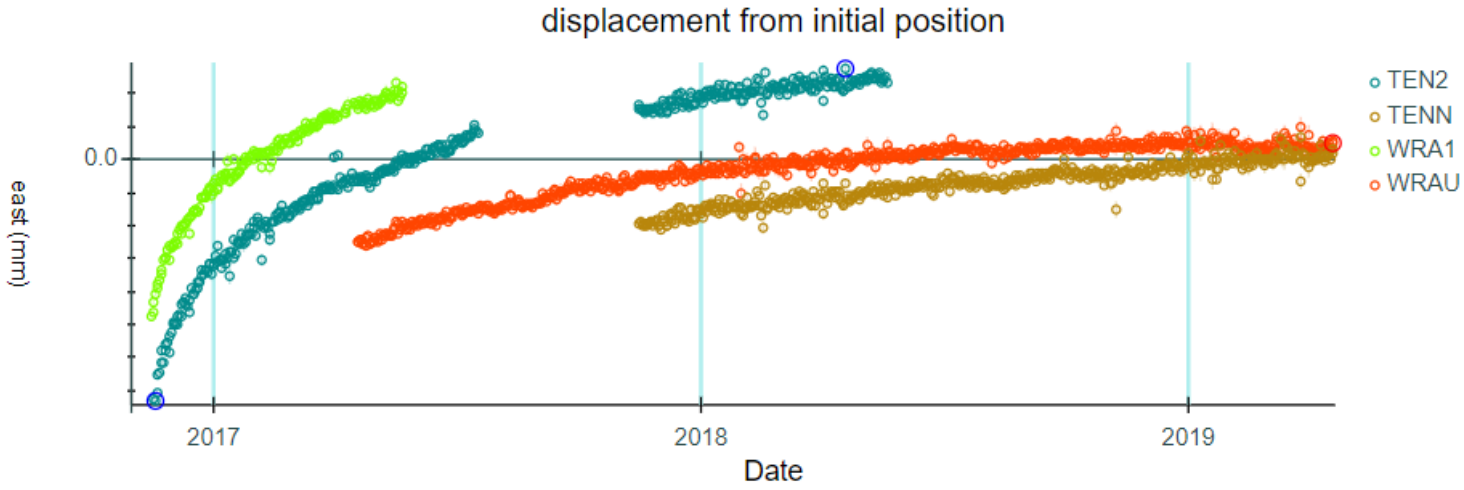
KEKS		Kekerengu



Kaikoura post-seismic ground deformation







GNSS stations in epicentral area used to better define post-seismic deformation. Important to study earthquake source and improve monitoring of aftershock sequence.

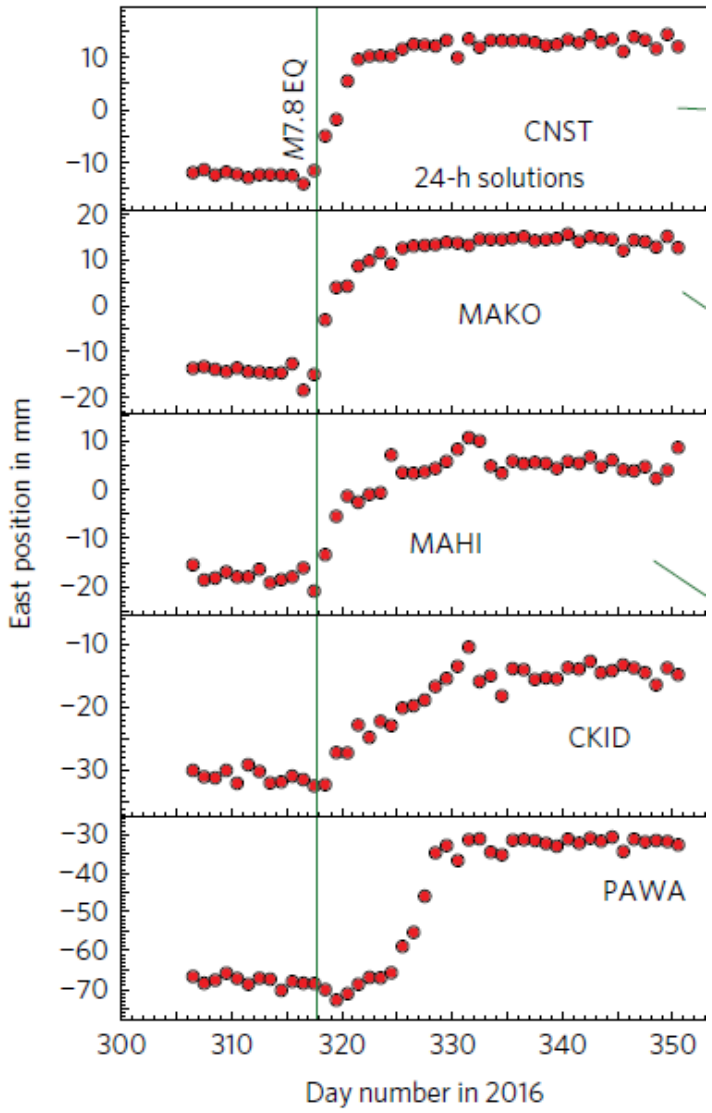
* *Temporary sites were made permanent within the next year, and co-located for at least a month with temporary deployments*

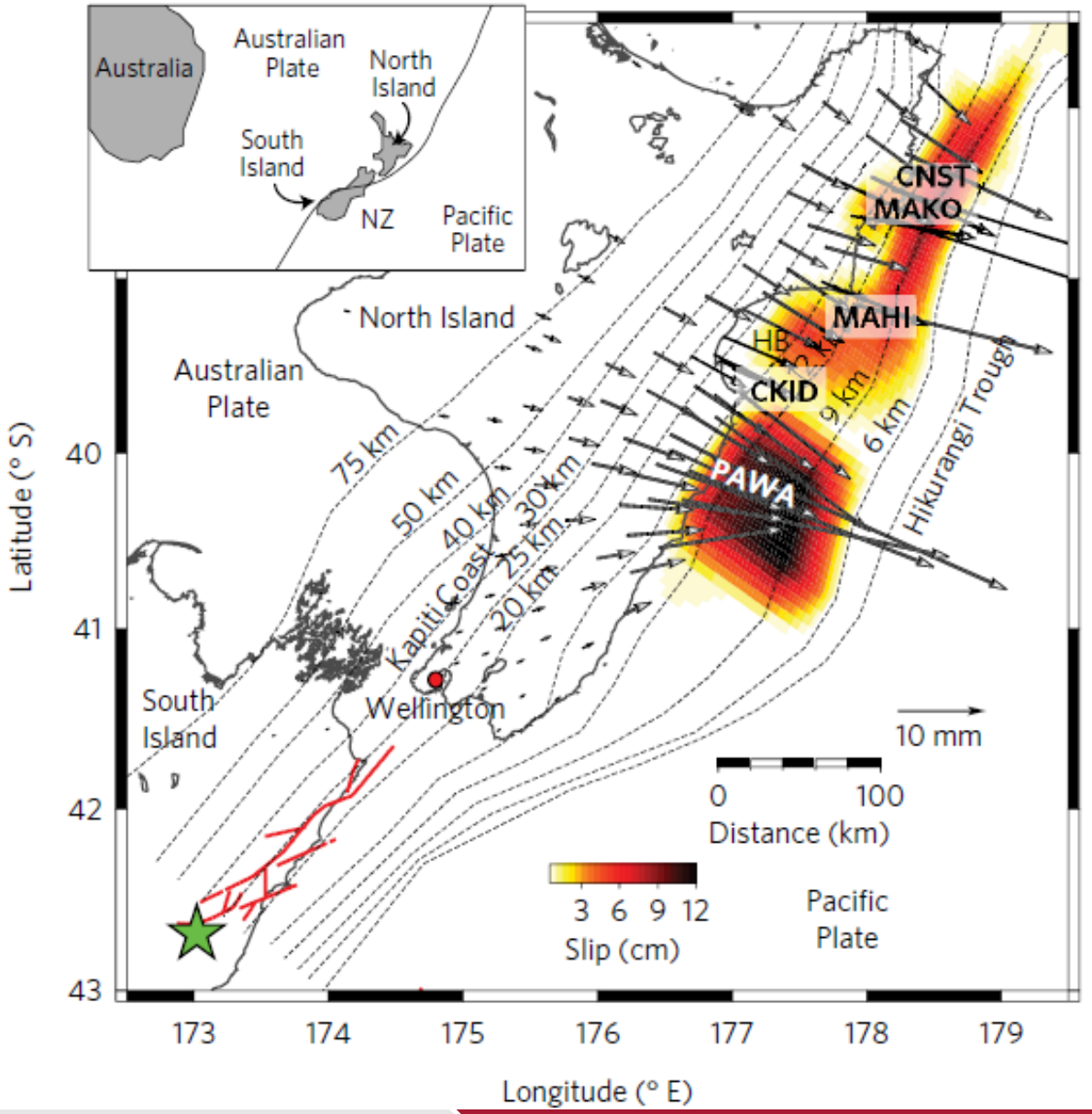
Kaikoura 2016: slow slip triggering

earthquake triggered a slow slip event on the Hikurangi subduction zone

Only observed by GNSS stations

after Wallace et al., NatGeo 2017





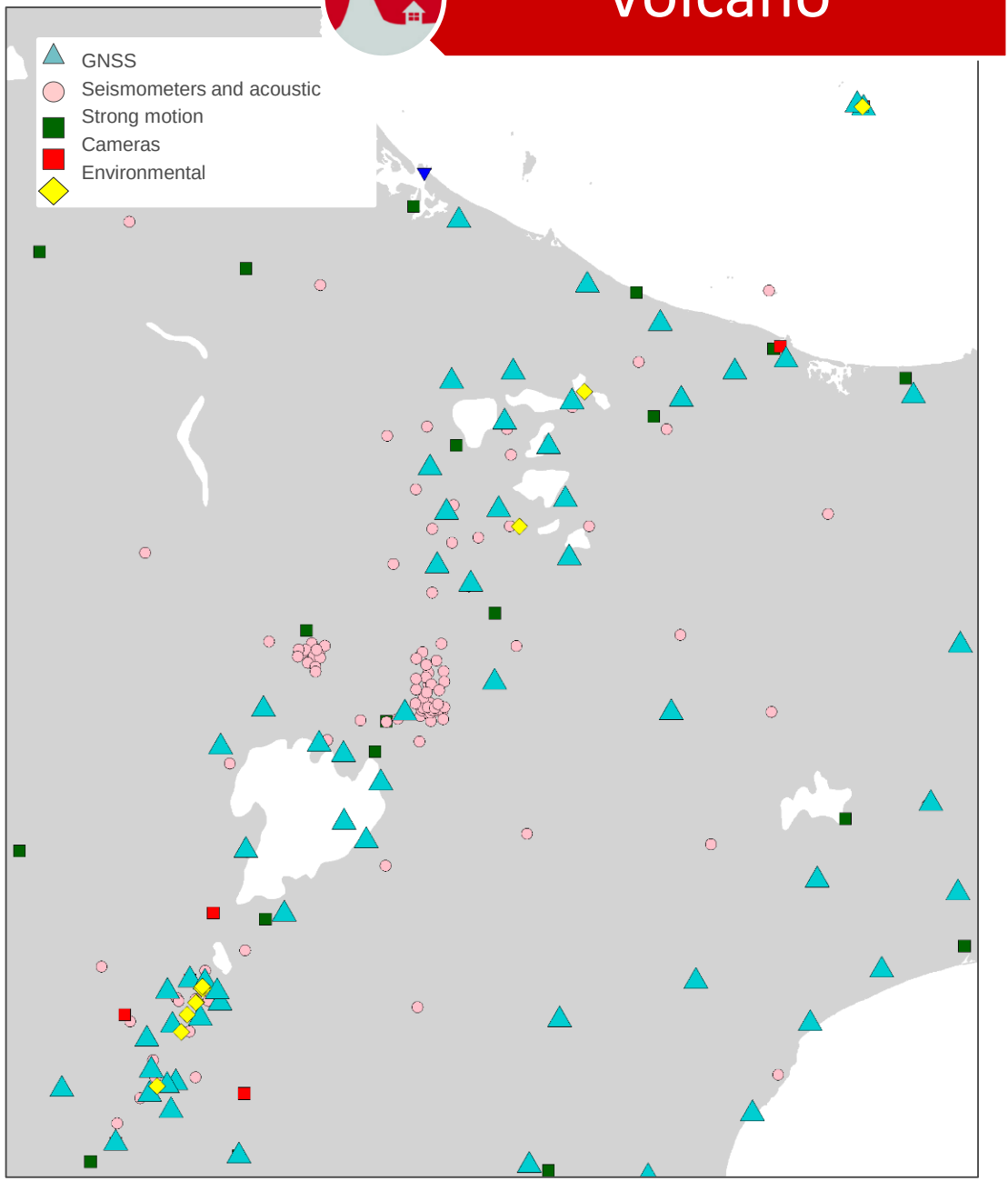
Kaikoura 2016, GNSS streaming enabled to support science and rebuild efforts

- **Where possible (depending on communication links), GeoNet stations in the epicentral area have been added to the PositioNZ-RT network**
  - Clarence river (CLR1-CLRR)
  - Cape Campbell (CMBL)
  - Wairau Valley (WRA1-WRAU)
- **GNSS streams have supported scientific studies and rebuild efforts**
  - Map faults' surface traces
  - Acquire LIDAR images in the epicentral area
  - Support the restoration of road and rail infrastructure
  - …..
- **Those GNSS streams are still available (and used)**

```
STR;CLRR00NZL0;Clarence River;RTCM 3;1004(1),1012(1),1006(10),1008(10),1013(10),1033(10);2;GPS+GLONASS;GeoNet;NZL;-42.14;173.81;0;0;Trimble NetR9;none;B;N;9600;Kaikoura eq response
STR;CMBL00NZL0;Cape Campbell No. 2;RTCM 3;1004(1),1012(1),1006(10),1008(10),1013(10),1033(10);2;GPS+GLONASS;GeoNet;NZL;-41.75;174.21;0;0;Trimble NetR9;none;B;N;9600;Kaikoura eq response
STR;WRAU00NZL0;Wairau Valley;RTCM 3;1004(1),1012(1),1006(10),1008(10),1013(10),1033(10);2;GPS+GLONASS;GeoNet;NZL;-41.59;173.59;0;0;Trimble NetR9;none;B;N;9600;Kaikoura eq response
```

Volcano monitoring

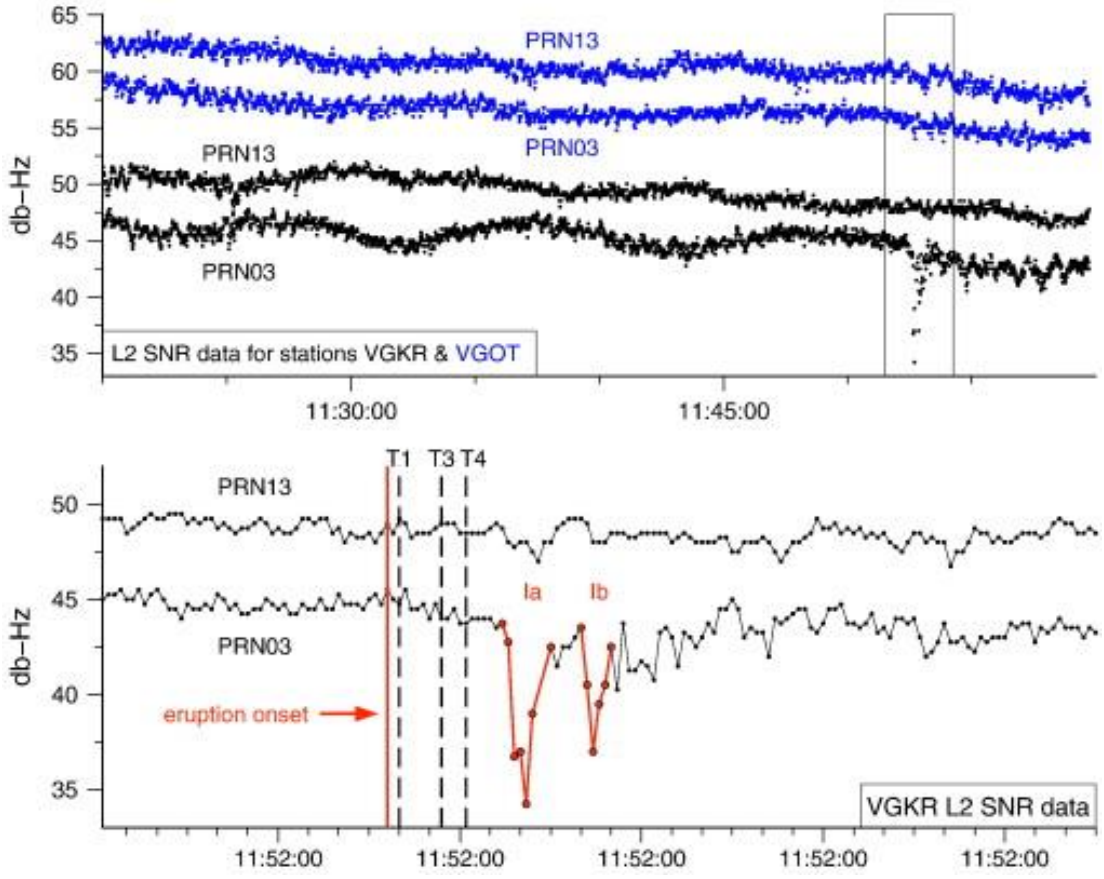
- GeoNet monitors 12 volcanoes/volcanic fields in New Zealand, including Raoul Island
- dedicated high density networks with co-located scientific equipment
- GNSS is used to monitor ground deformation of volcanic areas
- GNSS data are interpreted in combination with other data types and analyses

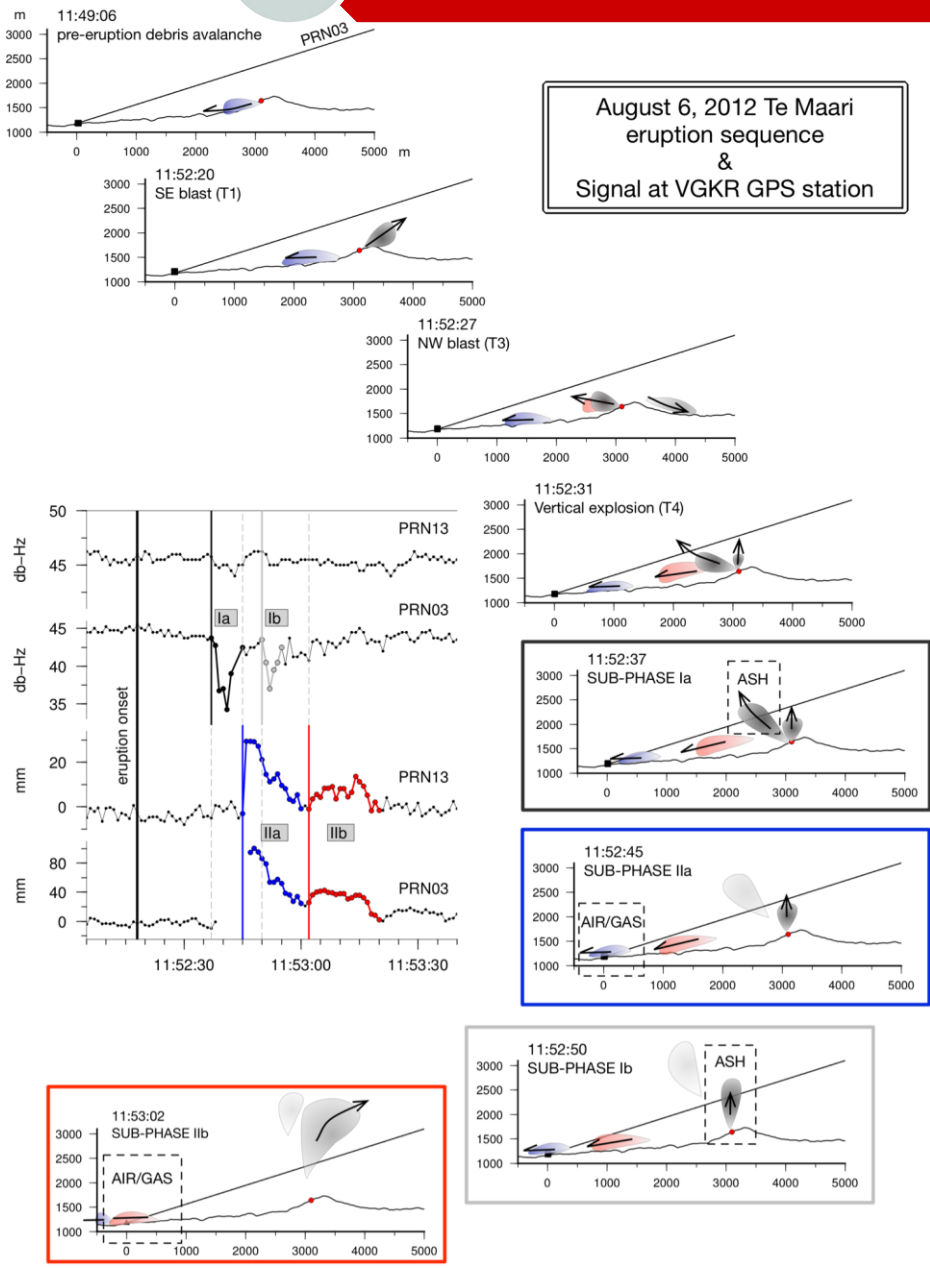


Te Maari 2012: alternative use of GNSS data

- GNSS signal to noise ratio (SNR) can be used to confirm presence of ash in volcanic plumes
- Te Maari 2012 eruption data

Fournier et al., 2014, https://doi.org/10.1016/j.jvolgeores.2014.05.021

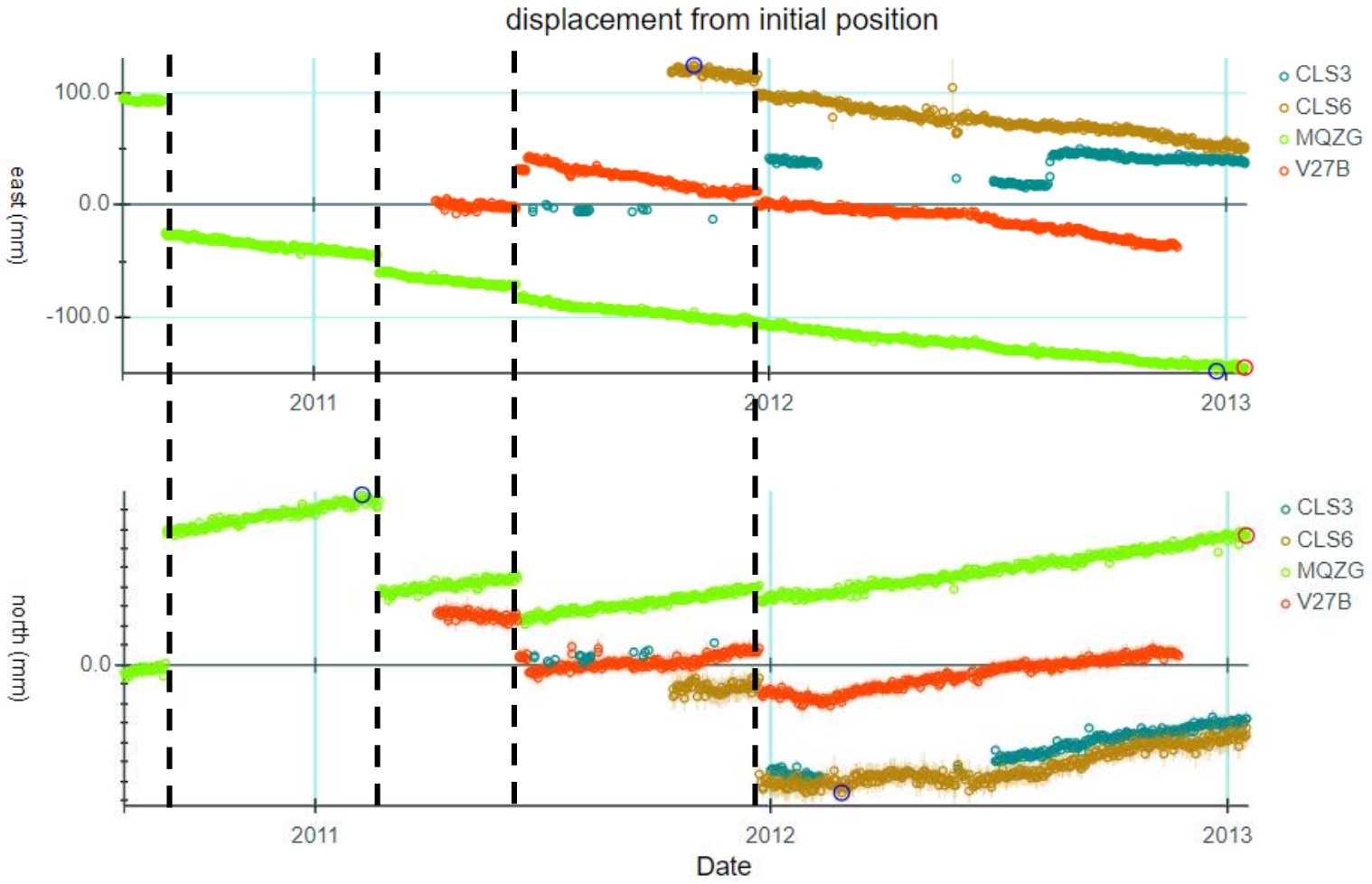




Port Hills, Christchurch Landslide Monitoring

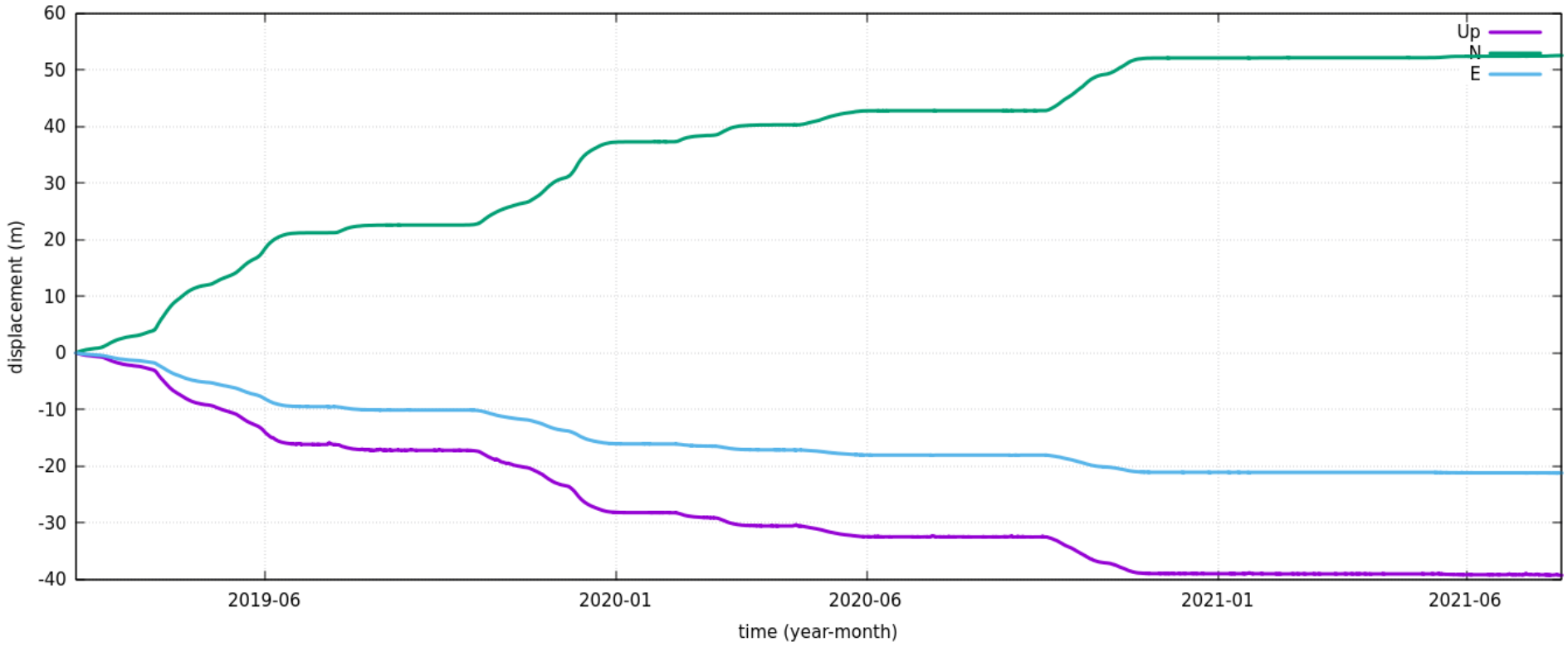
GeoNet installed and operated temporary GNSS stations to support scientific studies.
Landslide projects supported so far:

- Port Hills (Christchurch)
- Utiku
- Fox Glacier



2010-11 Canterbury earthquake sequence, M > 5.5 earthquakes

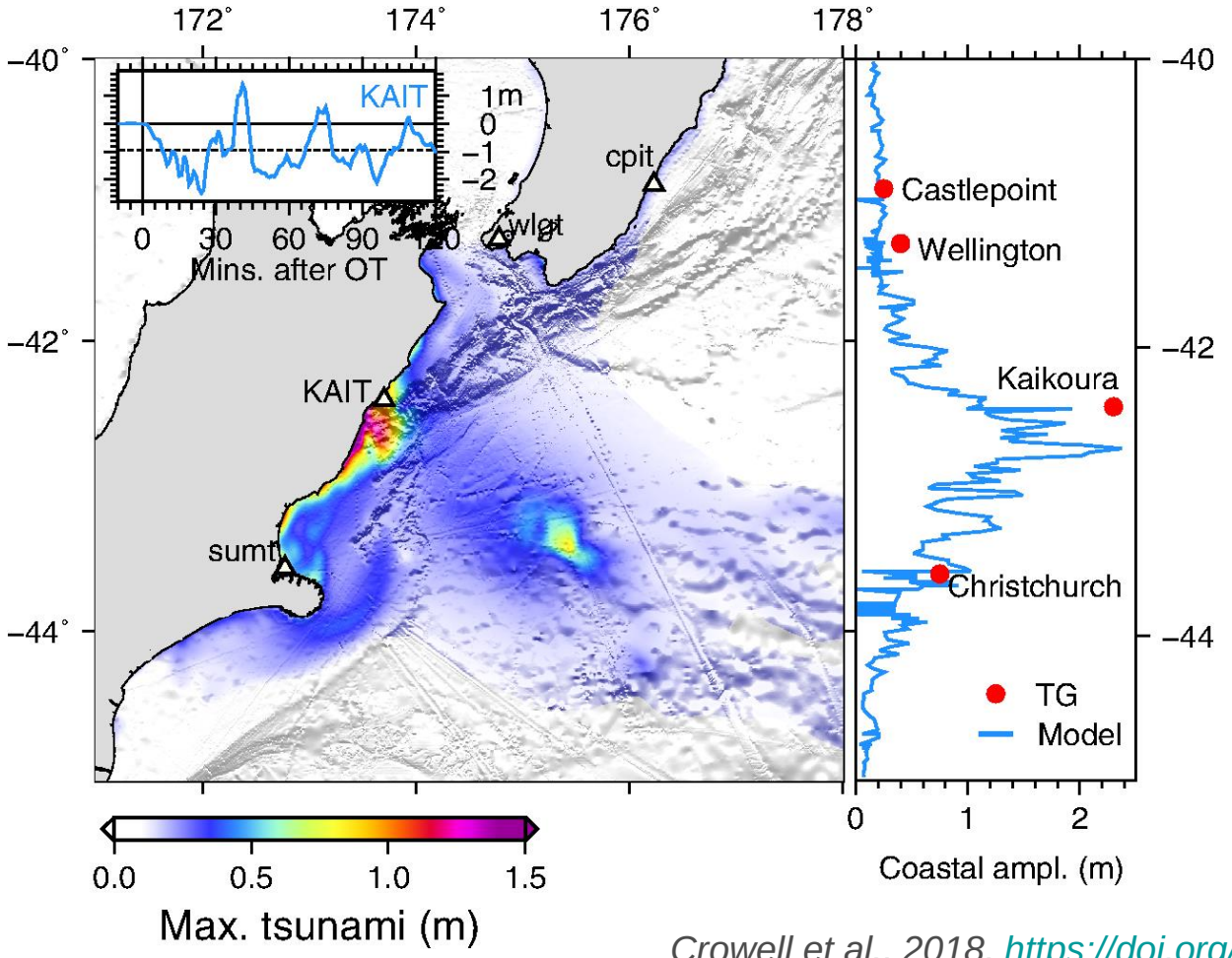
Landslide: Alpine Gardens Landslide (Fox Glacier)



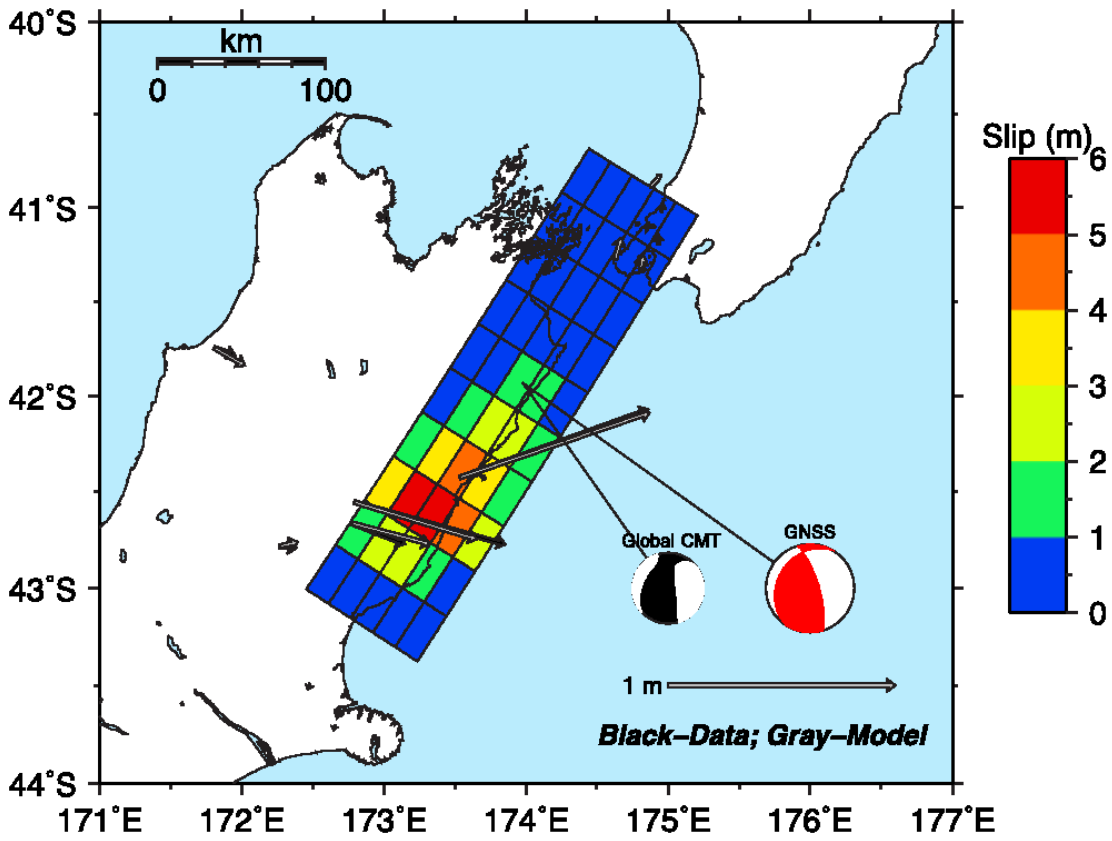
- Project funded by DOC
- GNSS monument specifically designed and installed by GeoNet
- Deployed in February 2019
- GNSS co-located with rainfall data logger
- GNSS station moved more than 60m since then!

Tsunami: Kaikoura 2016 simulation

post-event local tsunami modelling

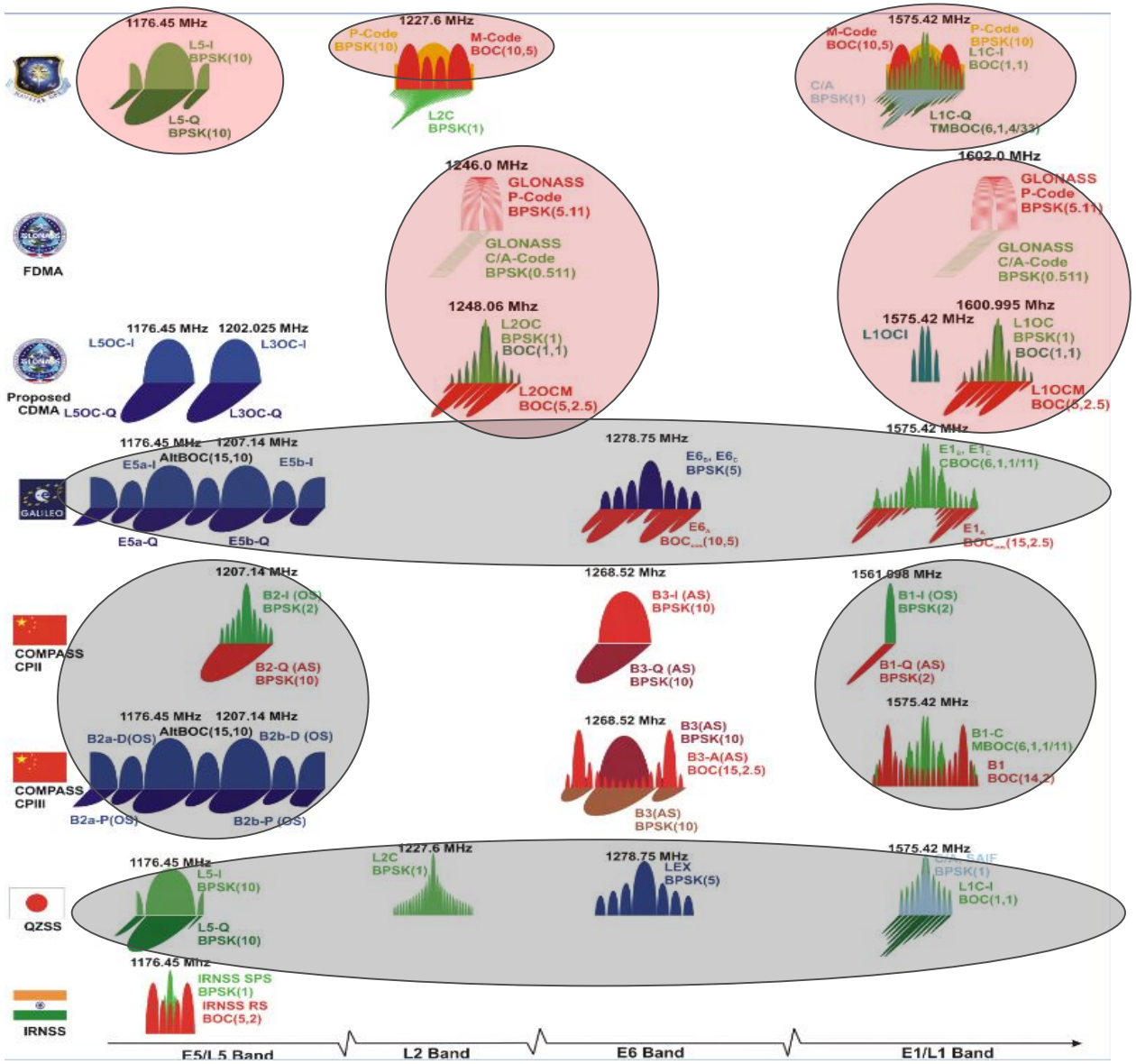


post-event simulation of earthquake source inversion using GNSS real time data

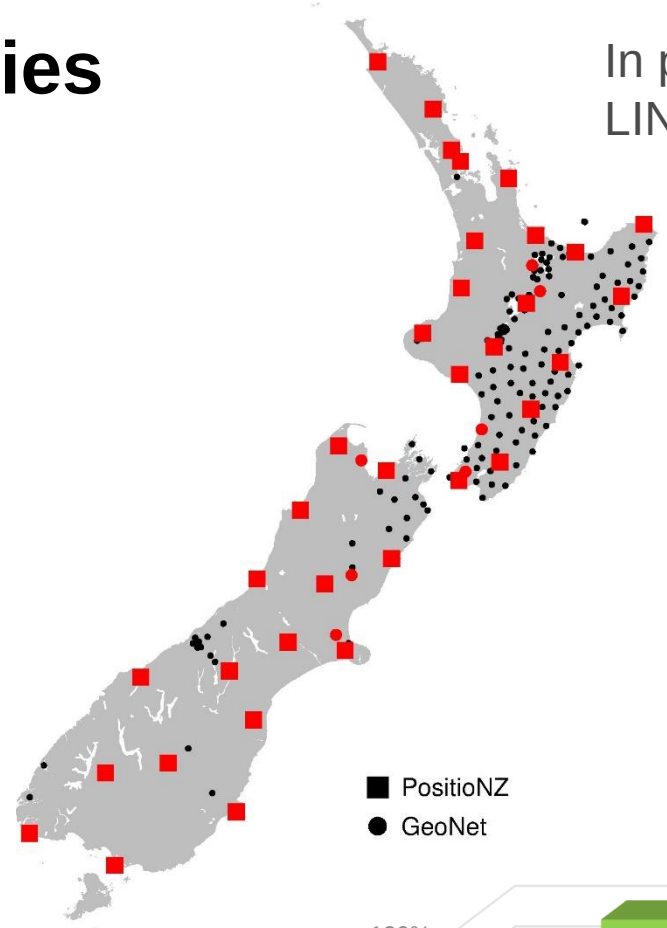


Crowell et al., 2018, https://doi.org/10.1785/0120170247

Future initiative: expand GNSS capabilities



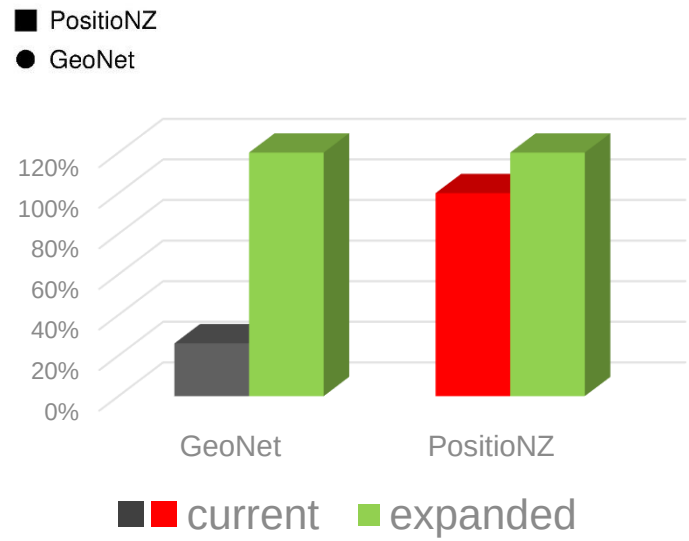
In partnership with LINZ and EQC



Tracking 2 GNSS constellations

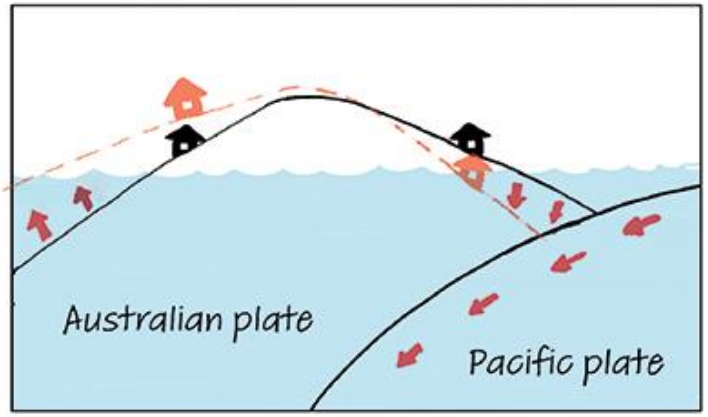
Tracking 5 GNSS constellations

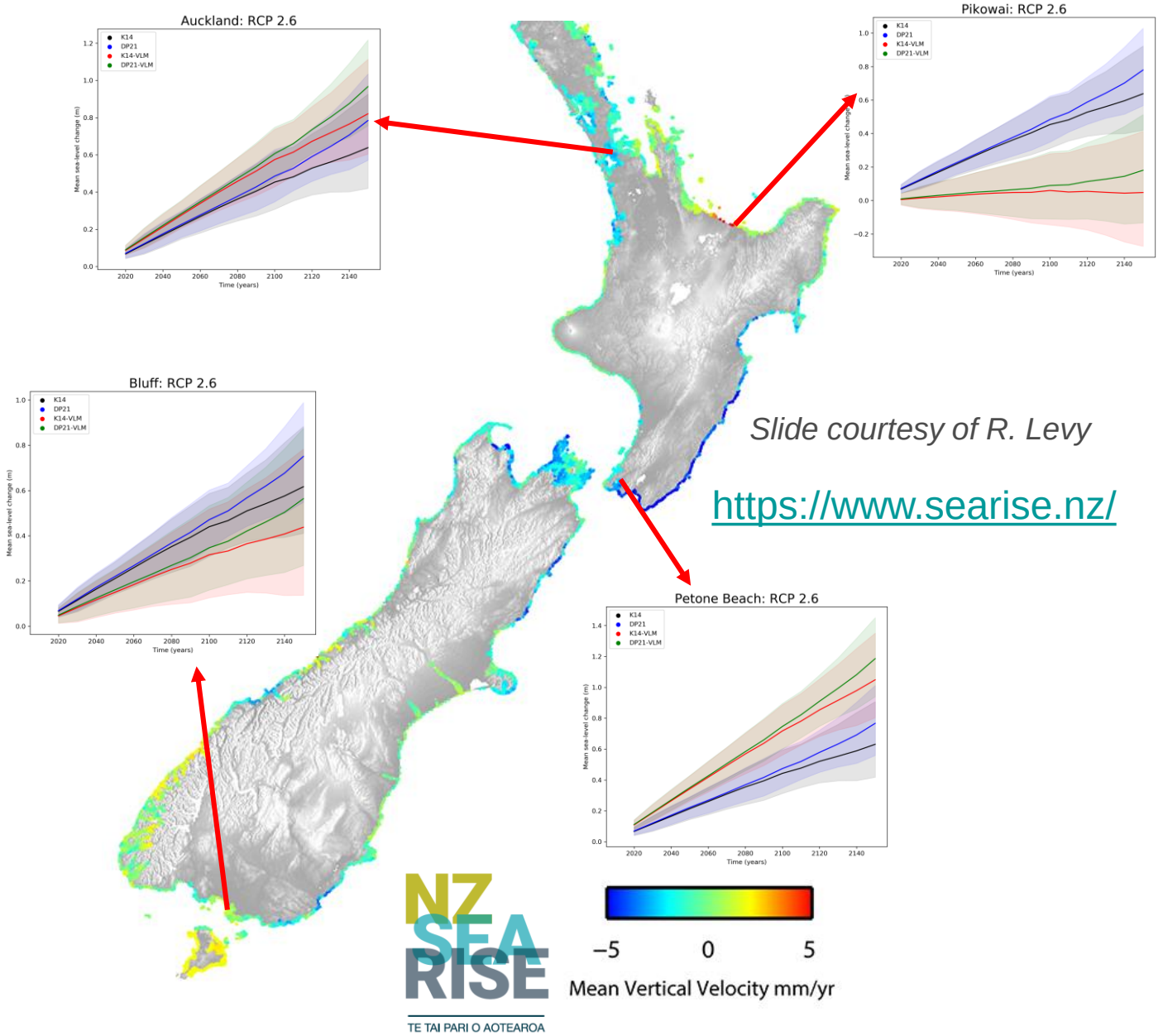
Estimated increase in data volumes (per station) if all GNSS signals are tracked



2018-2023 programme: sea level rise

Together with other data, GNSS will support understanding of vertical deformation along New Zealand coastlines, crucial to inform sea level rise forecasting models





Slide courtesy of R. Levy

https://www.searise.nz/

NZ SEA RISE
TE TAI PARI O AOTEAROA

Victoria University of Wellington Te Herenga Waka New Zealand | GNS Science Te Pū Ao | NIWA Taihoro Nukurangi | Ministry of Business, Innovation & Employment Hīkina Whakatutuki

2020-2025 programme: Rapid Characterisation of Earthquakes and Tsunami

MINISTRY OF BUSINESS, INNOVATION & EMPLOYMENT
HĪKINA WHAKATUTUKI

GNS SCIENCE TE PŪ AO

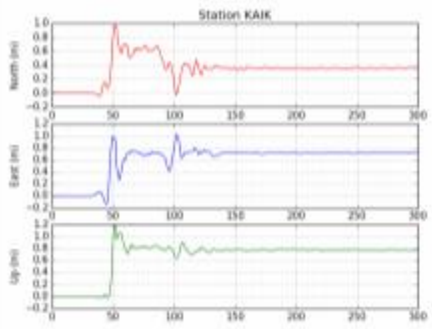
ShakeAlert trigger

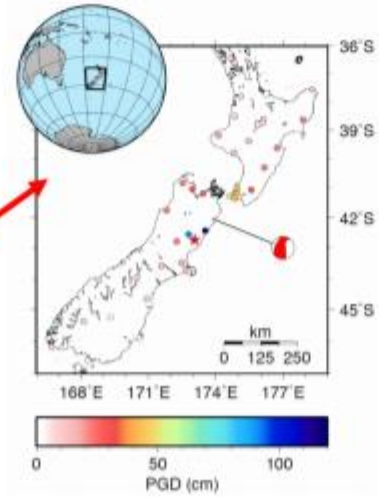
Geodetic modeling modules

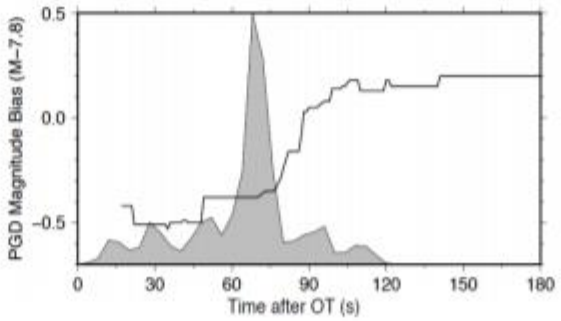
PGD scaling

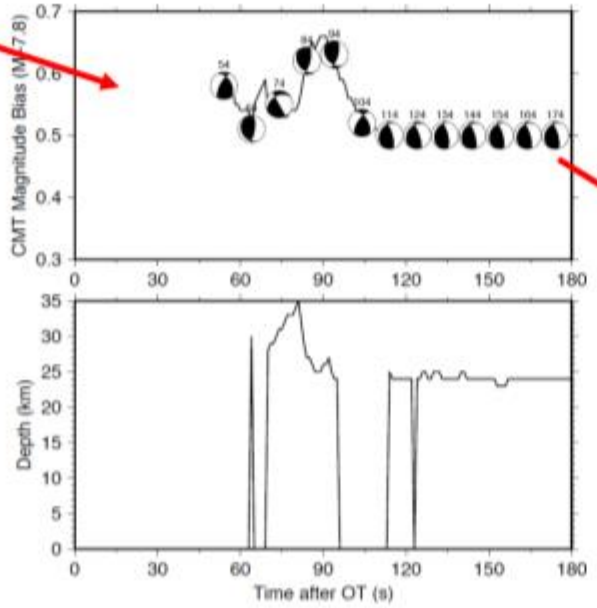
CMT-driven Finite Fault (FF) inversion

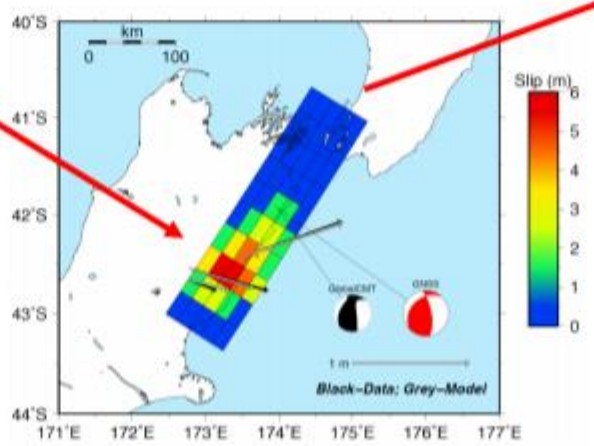
GNSS Waveforms

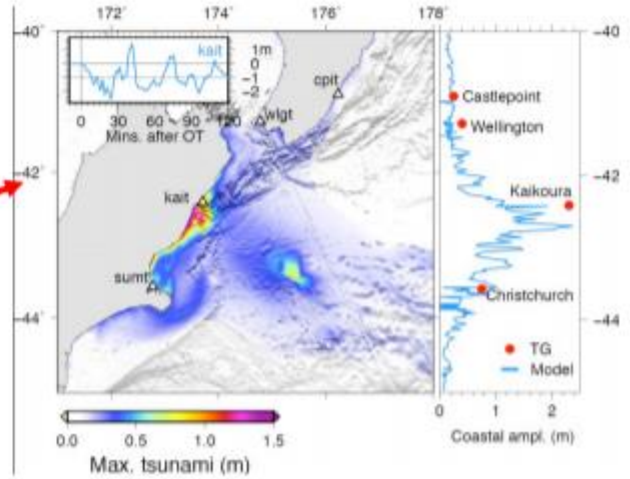


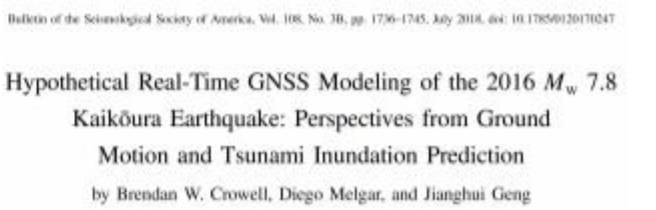












Taking output of G-FAST's FF inversion will help aid in near-field tsunami forecasts

Crowell et al., 2018, https://doi.org/10.1785/0120170247

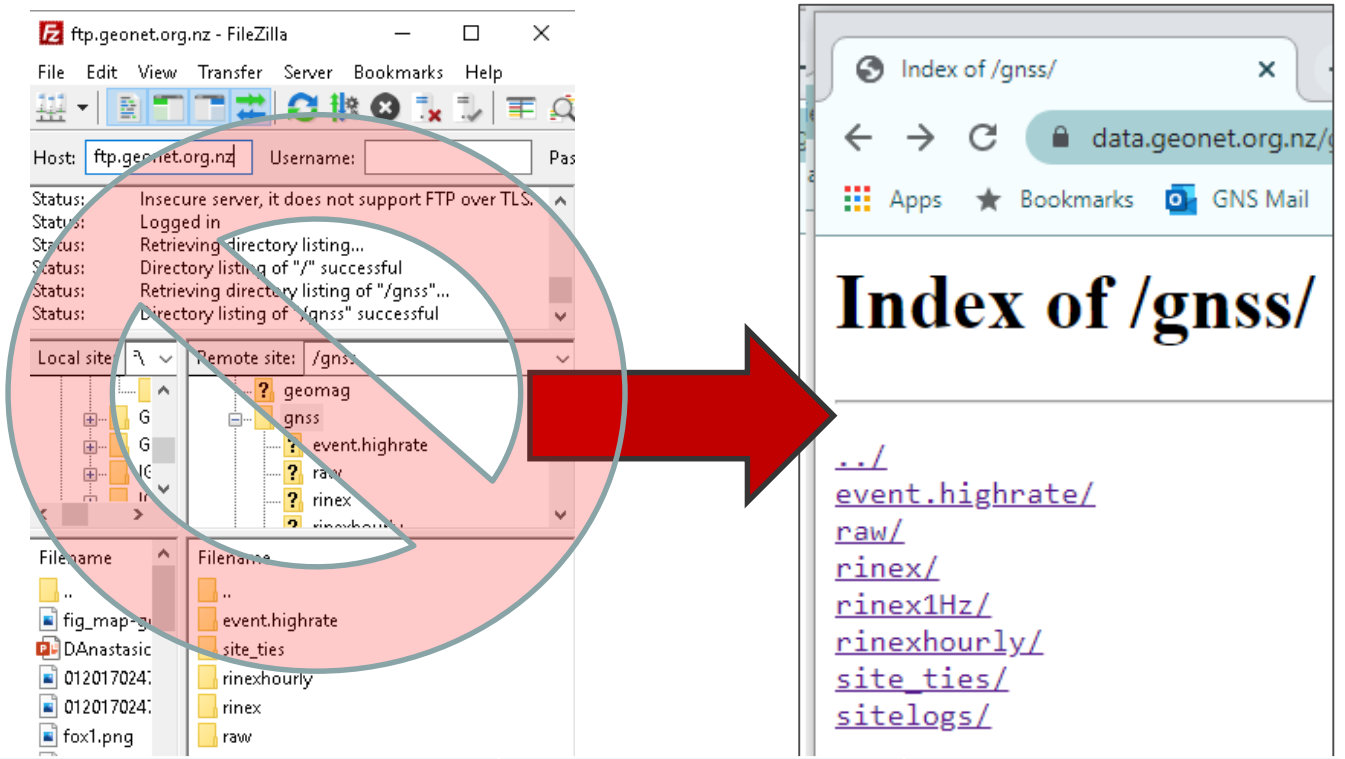
Last but not least….

Deprecation of GeoNet FTP server

FTP now deprecated by all internet browsers

- ftp://ftp.geonet.org.nz will be decommissioned in **early 2022** to comply with IT security requirements
- GeoNet GNSS data are now distributed over HTTP: **https://data.geonet.org.nz**

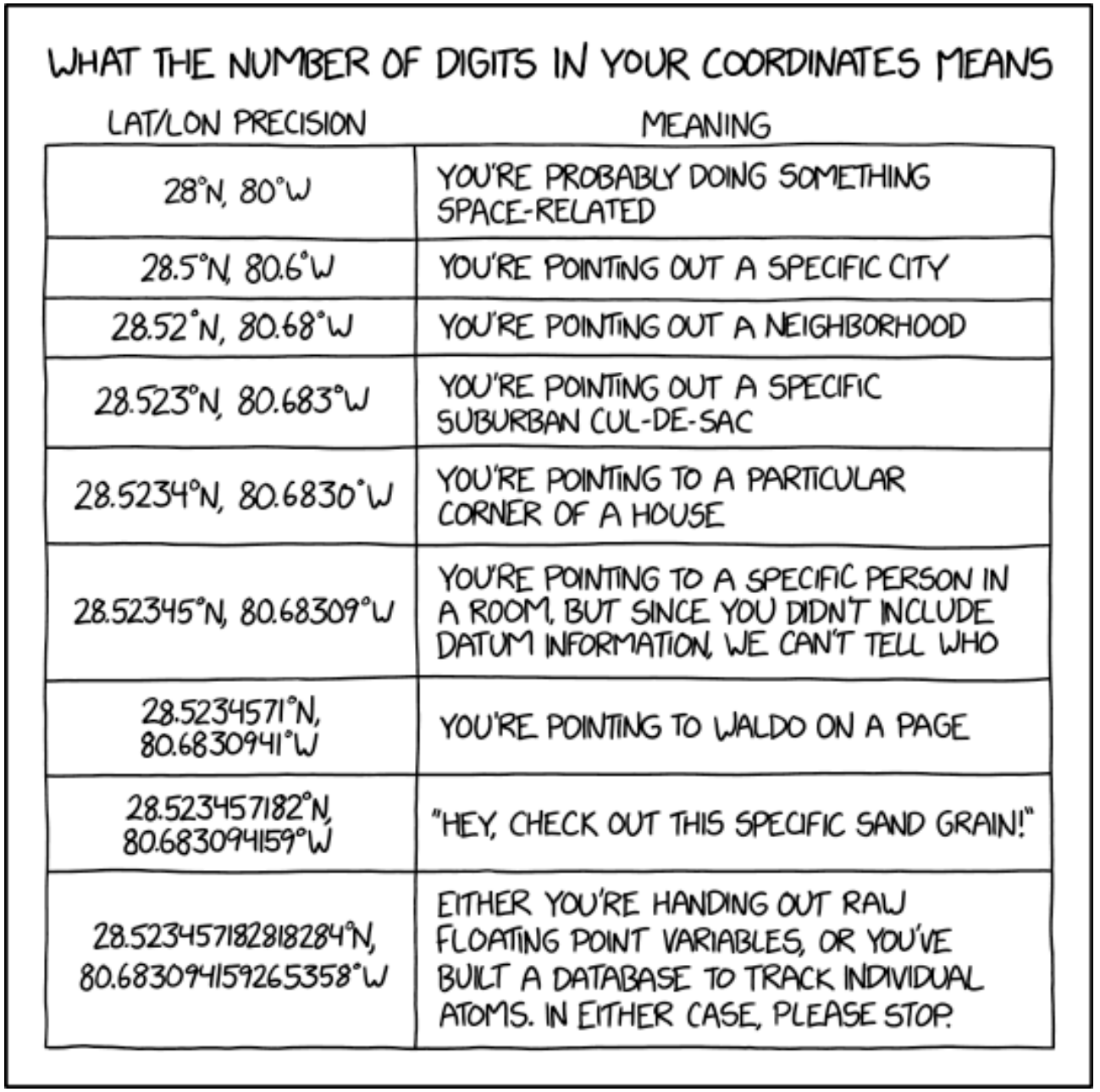
Please contact me or info@geonet.org.nz if you want to be notified of the change happening and exact timeline



GNSS product	Current (FTP)	New (HTTPS)
30s raw	gnss/raw	gnss/raw
30s rinex, hourly	gnss/rinexhourly	gnss/rinexhourly/
30s rinex, daily	gnss/rinex	gnss/rinex
1s rinex, 15min (PositioNZ-RT)	rtgps/rinex1Hz/PositioNZ	gnss/rinex1hz
event highrate data	gnss/event.highrate	gnss/event.highrate
Site ties	gnss/site_ties	gnss/site_ties
sitelogs	gps/sitelogs	gnss/sitelogs

Grazie
Kia Ora
Thank you!

e.danastasio@gns.cri.nz



https://xkcd.com/2170/